RUFORUM Working Document Series (ISSN 1607-9345), 2019, No. 18 (1): 436 - 451
Available from http://repository.ruforum.org

Research Application Summary

Enhancing pig production and marketing for smallholder farmers in Northern Uganda

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Abstract

In Uganda, pig production is constrained by unsustainable use of local feedstuffs, poor breeds, odour in pig houses, and lack of access to critical market information. This project aimed to address the key constraints by promoting sustainable breeding, management and marketing. Community Action Research (CAR) was conducted where smallholder pig farmers and graduate students were engaged in innovations, experience sharing, joint learning, active participation, and dissemination of the findings. Results from CAR showed that males (50.7%) kept pigs as well as females (49.3%), with each household keeping three pigs. Most farmers kept local breeds (63.2%); sold live pigs (71.6%); and none was using artificial insemination (AI), feed formulae from local feedstuffs, and indigenous microorganisms (IMO) for pig production. Fresh cassava leaves (70.0%), sweet potato vines (56.0%), and rice bran (44.5%) were the common feedstuffs for feeding pigs. Most feedstuffs were not readily available throughout the year. Most (77.2%) farmers used both local and commercial feeds while 90.6% fed pigs entirely on local feedstuffs. Unit cost of producing a local feed was lower (Ugx 213.1) than that of producing a commercial feed (Ugx 963.0). Most (70%) farmers were aware of existence of AI and were positive about its use. However, perception to use AI was more positive in male pig farmers than in females. Perceived usefulness of AI had a positive influence on intentions to use AI. Molasses medium was more effective in multiplication of IMO than maize bran where total viable cell counts in molasses were $360x10^2$cfu/gram while that of pure maize bran was $288x10^2$cfu/gram. When IMO solution was applied on deep litter floor, no odour was detected above 10 meters from the house while the odour was not detected above 40 meters from the house when IMO was not applied. Pig growth, nutrient composition of pork, back fat thickness and acceptability of roasted and deep fried pork were not affected ($p \geq 0.05$) whether IMO solution was applied or not on deep litter floor. Pork from pigs raised on IMO treated and untreated deep litter floors had 88.9% unsaturated fatty acids. Pork was most consumed meat product where ham and ribs were the most preferred parts. Freshness, aroma and taste were the most important attributes consumers considered when purchasing pork. Farmers who had access to extension services were 7.6% more adaptive and 6.6% more able to modify existing pig production practices. Farmers who sold pork were found to be 16.8% and 19.4% more able to adapt new practices and modify existing practices, respectively. Farmers who relied on pig traders for market information had a lower likelihood to scan their environments or test new pig rearing practices. Farmers who used market information to make decisions on how to rear pigs had a higher innovative activity and creativity. Research findings were disseminated to 300 pig farmers. Three MSc. students passed Viva voce examination, dissertation of the 2 students are being examined and 3 students are compiling their reports. Twelve pig AI technicians were trained to offer AI services to pig farmers. Community engagement has created a great avenue for increasing household incomes through pig production.

Key words: Breeding, deep litter floor, local feed, market information, odour, pig production

Résumé

En Ouganda, la production porcine est limitée par l'utilisation non durable des aliments pour bétails locaux, les races peu productives, les odeurs dans les porcheries et le manque d'accès aux informations essentielles sur le marché. Ce projet visait à juguler ces principales contraintes en promouvant l'élevage, la gestion et la commercialisation durables. Une recherche-action communautaire (RAC) a été menée, regroupant les petits éleveurs de porcs et les étudiants tous ensemble engagés dans des innovations, le partage d'expériences, le programme conjoint d'apprentissage, la participation active et la vulgarisation des résultats. Les résultats de la RAC ont montré que les hommes (50,7 %) élevaient des porcs et contre 49,3 % des femmes, et que chaque ménage possédait en moyenne trois porcs. La plupart des fermiers élevaient des races locales (63,2 %), vendaient des porcs vivants (71,6 %) et aucun d'eux n'utilisait l'insémination artificielle (IA), les formules alimentaires à base d'aliments pour bétails locaux et les micro-organismes indigènes (MOI) pour la production porcine. Les feuilles de manioc fraîches (70,0 %), les tiges de patate douce (56,0 %) et le son de riz (44,5 %) étaient les aliments les plus couramment utilisés pour l'alimentation des porcs. La majorité des aliments n'étaient pas facilement disponibles tout au long de l'année. La plupart des agriculteurs (77,2 %) utilisaient à la fois des aliments locaux et commerciaux, tandis que 90,6 % nourrissaient leurs porcs entièrement avec des aliments locaux. Le coût unitaire de production d'un aliment local était inférieur (213,1 Ugx) à celui de la production d'un aliment commercial (963,0 Ugx). La majorité des éleveurs (70 %) étaient conscients de l'existence de l'IA et avaient un avis positif quant à son utilisation. Cependant, la perception de l'utilisation de l'IA était plus positive chez les hommes que chez les femmes. La perception de l'utilité de l'IA a eu un effet positif sur les intentions d'utilisation de l'IA. La mélasse comme milieu de culture était plus efficace pour la multiplication des micro-organismes indigènes que le son de maïs, le nombre total de cellules viables dans la mélasse étant de $360x10^2$cfu/gramme contre $288x10^2$cfu/gramme dans le son de maïs pur. Lorsque la solution des micro-organismes indigènes a été appliquée sur le sol de la litière profonde, aucune odeur n'a été détectée à plus de 10 mètres de la porcherie alors que l'odeur avait été détectée à plus de 40 mètres de la porcherie lorsque la solution des micro-organismes indigènes n'avait pas été appliquée. La croissance des porcs, la composition nutritive du porc, l'épaisseur de la graisse dorsale et l'acceptabilité du porc rôti et frit n'ont pas été affectées ($p \geq 0,05$) par l'application ou non de la solution des micro-organismes indigènes sur le sol en litière profonde. La viande de porc provenant de porcs élevés sur des sols à litière profonde traités et non traités par la solution des micro-organismes indigènes contenait 88,9 % d'acides gras insaturés. Le porc est le produit carné le plus consommé, le jambon et les côtes étant les parties les plus appréciées. La fraîcheur, l'arôme et le goût étaient les attributs sensoriels les plus importants considérés par les consommateurs lors de l'achat de la viande de porc. Les éleveurs ayant accès aux services de vulgarisation étaient 7,6 % plus aptes à s'adapter et 6,6 % plus aptes à modifier les pratiques de production porcine existantes. Les éleveurs qui vendaient de la viande de porc étaient 16,8 % et 19,4 % plus aptes à s'adapter aux nouvelles pratiques et à modifier les pratiques existantes, respectivement. Les éleveurs qui dépendaient des négociants de porcs pour obtenir des informations du marché étaient moins susceptibles d'analyser leur environnement ou de tester de nouvelles pratiques d'élevage de porcs. Les éleveurs qui utilisaient les informations du marché pour prendre des décisions sur la manière d'élever les porcs étaient plus innovants et avaient une créativité plus élevée. Les résultats de la recherche ont été vulgarisés auprès de 300 éleveurs de porcs. Trois étudiants en Master ont réussi leur soutenance de thèse, les mémoires de deux étudiants sont en cours d'examen et trois autres étudiants sont en train de rédiger leurs rapports. Douze techniciens en IA ont été formés pour offrir des services d'IA aux éleveurs de porcs. L'implication et la participation de la communauté a permis d'augmenter les revenus des ménages grâce à la production porcine.

Mots clés : Élevage, sol à litière profonde, aliment local, informations sur le marché, odeur, production porcine.

Introduction

Pig production and marketing have the potential to improve the livelihoods of smallholders (Muhanguzi *et al*., 2012) because pigs are characterized by faster growth rates, high multiplication rates, and feed on many agri-products (Ndyomugyenyi and Kyasimire, 2015). In Uganda, the central dominates (56%) in pig production while northern region is the least with only 14% pig farmers (Tatwangire, 2012). Pig population has not significantly changed over the years as indicated by the population of 3.58, 3.69 and 3.58 million in 2012, 2013 and 2014, respectively (UBOS, 2015). A number of opportunities exist such as increase in human population, incomes and the number of pork facilities in rural and urban areas that could be exploited to increase pig production (Mulindwa, 2016). Despite the opportunities, pig production and marketing in Uganda are constrained by high cost of quality feeds; poor breeds; foul smell in pig houses; and markets are not reliable for live pigs and products (Ouma *et al*., 2013).

At 60-80%, feeding costs accounts for the largest proportion of livestock production costs (Thu Hong and Thanh Ca, 2013). The increasing cost of conventional feedstuffs for livestock production necessitates the need to find less expensive alternatives (Thu Hong and Thanh Ca, 2013). Although non-conventional feedstuffs are less costly alternatives, farmers are not aware of their nutritional composition, and therefore cannot formulate a balanced diet for pigs (Ndyomugyenyi and Kyasimire, 2015). There is need to formulate diets from alternative feedstuffs for smallholder pig production.
The use of artificial insemination (AI) as alternative to natural mating could improve pig breeding and reduce cost associated with boars. The use of AI reduces movement of boars, hence minimizing disease transmission, and inbreeding (Ndyomugyenyi and Kyasimire, 2015). However, using AI is expensive due to the cost of storing semen, and unaffordable by smallholders (Muhanguzi *et al*., 2012). Additionally, keeping boars for breeding is costly for smallholders who are characterized by rearing few sows (Ndyomugyenyi and Kyasimire, 2015). The cost of AI services could be reduced using local semen extenders as alternative to commercial extenders.

Managing foul smell emitted from pig units is one of the major challenges in pig production. Although methods to reduce foul smell from piggeries have been proposed (Chastain, 2003), they are expensive and therefore unaffordable by smallholder farmers. The use of Indigenous microorganisms (IMO) has been suggested as a less costly alternative (Ndyomugyenyi and Kyasimire, 2015) but its effectiveness under local housing settings has not been fully established.
To ensure profitability, smallholder pig farmers need to access critical market information such as market location, type of product demanded, quality standards and when the product is demanded (Muhanguzi *et al*., 2012). The challenge affecting the marketing of pigs in Uganda is lack of understanding of key customers, their interests in terms of quantity, quality and trends in demand (Mulindwa, 2016). This arises due to inadequate access to market information in pig markets (Ouma *et al*. 2016). Enhancing profitable market participation along the value chains strengthens the competitiveness of the value chains and ensures increased income status of smallholders (KIT and IIRR, 2010). There is need to identify and classify primal markets and customer segments for pigs and pig products. Through this, consumers will be classified into relevant segments by products demanded, income, location, seasons and behaviour. This will enable pig farmers to target specific market segments with specific product, hence increasing the profitability of the pig enterprise.

To enable smallholders to improve their livelihoods through pig production, there is urgent need to look for ways of reducing the constraints. Therefore, the project described in this paper aimed to contribute to improved household livelihoods through promotion of sustainable breeding, management and marketing in pig value chain in northern Uganda. The project hopes to achieve the following objective: (1) promoting the efficient use of diets from local feedstuffs; (2) testing and disseminating the use of indigenous micro-organisms for reducing foul smell in pig housing; (3) evaluating and promoting the use of local semen extenders in artificial insemination; (4) assessing, promoting the profitable market linkages and establishing effective information for farmers. The specific hypotheses for each objective were developed by graduate students undertaking different research components.

The project envisioned three primary result areas: (1) Capacity building (19 students trained including 1 PhD, 8 MSc and 10 BSc; 12 pig AI technicians trained to offer AI services to pig farmers; 750 farmers trained to use AI for pig breeding); (2) Sustainable pig production technologies developed (local feed formulae for production of pigs with quality output; local semen extenders to substitute more costly commercial extenders in AI; IMO products to reduce smell from pig houses); (3) Profitable market linkages developed (pig marketing groups formed; groups linked to agri-business incubation centre to exhibit the developed technologies; communication platform to link the marketing groups with potential pig markets; central pork processing unit established to train farmers on value-added pork products).

Methodology

The project was conducted in Gulu and Omoro districts (longitude 30-32°E, latitude 02-4°N), northern Uganda. A two-category multi-stakeholder platform was used: (1) Technical and Vocational Training Institution (TVET) and University students; and (2) farmers, private sector (traders, pork consumers), and Community Based Organization (CBO) (Figure 1). The stakeholders were engaged in innovations, research, sharing experiences, joint learning, active participation, and dissemination of the findings.

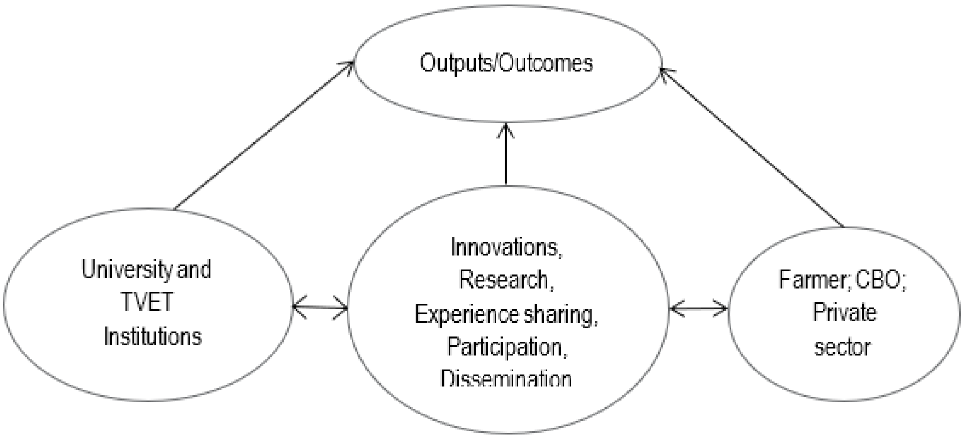

Figure 1. Institution-community interaction in CAR

Before the research activities started, inception meeting was held (Figure 2). Following the meeting, a baseline survey was conducted to obtain the underpinning data on pig value chain

Figure 2 Stakeholder meeting attended by 49 stakeholders in October 2017 included representatives from ILRI; Regional Coordinator, Operation Wealth Creation; 5 representatives from CBO, TVET and Private Sector. District Production Department; Vice Chancellor; HODs; PhD and MSc. students

The CAR design and description is summarized in Figure 3. The design shows how research activities, outputs, outcomes and impact are interrelated.

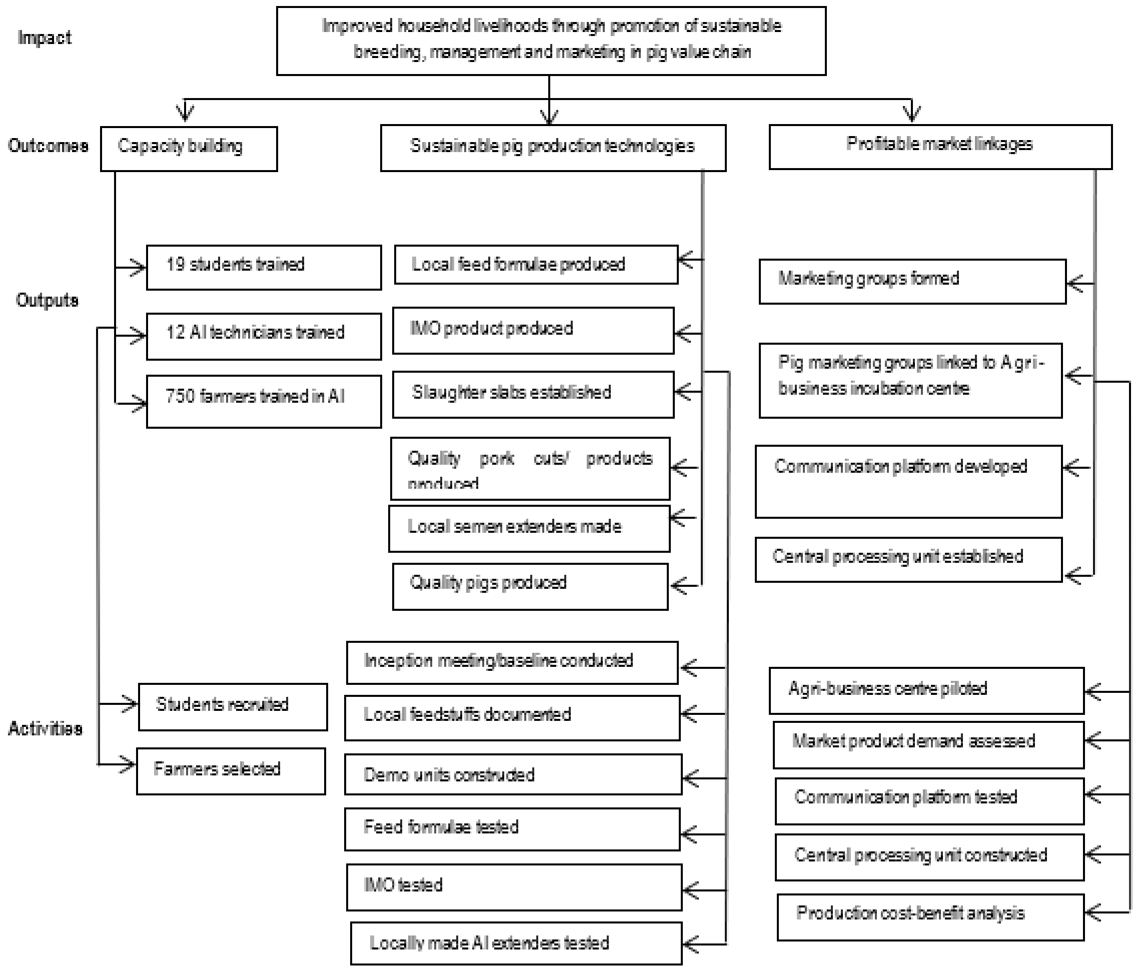

Figure 3. CAR Design

Results and Discussion

Community engagement and student progress. Through student engagement with communities, 300 pig farmers were trained to use IMO technology (Figure 4) and formulation of feed from local feedstuffs (Figure 5). The IMO products from molasses and maize bran were also produced (Figure 6). Research findings were disseminated back to the 300 pig farmers by MSc students (Figure 7). Three MSc. students passed Viva voce examination and are waiting for the graduation; dissertations of the two students are being examined and three students (including PhD student) are compiling their reports. Twelve pig AI technicians were trained to offer AI services to pig farmers (Figure 8).

Overview of pig production among smallholder farmers in Northern Uganda. Males kept pigs as well as females, with each household keeping three pigs (Table 1). This finding agrees with a study by Tatwangire (2014). Women provide most of the labour force in pig production, and thus have a higher participation (Ikwap *et al*., 2014). Most farmers attained the primary level of education and this is comparable to the findings of Muhanguzi *et al*. (2012) and Ikwap *et al*. (2014). At this level of education and age bracket of 50 years, it would be difficult for married farmers to get a decent employment somewhere else, hence resorting to farming and specifically pig production as the main source of income.

Figure 4. Farmers engaged in the construction of IMO demonstration units

Figure 5. Low-cost feed formulae from sweet potato vines, fresh cassava tubers and rice bran

Figure 6. IMO products from molasses and maize bran

Figure 7. MSc student disseminating results to pig farmers

Figure 8. A group of AI technicians equipped to offer AI services to pig farmers

Table 1. Socio-demographic characteristics of the respondents

Variable	No. of respondents (N = 205)	% of respondents
Gender		
Male	104	50.7
Female	101	49.3
Age (years)		
14-35	83	40.5
36-64	117	57.1
Marital status		
Married	160	78.0
Single	22	10.7
Level of education		
No formal education	12	5.9
Primary	122	59.5
Secondary	52	25.4
Tertiary	19	9.3
Herd size		
0	96	46.8
1-5 Pigs	74	36.1
6-10 Pigs	28	13.7
Above 10 Pigs	7	3.5

Feeding, breeding and use of IMO technology in pig production. Most pig farmers fed their pigs on local feedstuffs (Table 2). Commercial feeds are usually costly and unaffordable by smallholders (Ikwap *et al*., 2014; Tatwangire, 2014). Developing formulae from less costly local feedstuffs and supplementation with commercial feeds could be an alternative to farmers who cannot afford to feed pigs on commercial feeds. Most farmers kept local breeds (63.2%) and sold live pigs (71.6%).

No farmer was using artificial insemination and IMO technologies. All the farmers used natural mating to breed their sows. The challenge with natural mating is disease transmission when a boar is moved from sow to sow on another farmers' herd (Ndyomugyenyi and Kyasimire, 2015). Farmers could use artificial insemination (AI) to access superior boars for increased pig production. This would be possible if local extenders were used and there is availability of local stationed AI technicians to provide the AI service to the communities. The IMO system is known to reduce smell from pig houses and is less costly to establish (Ndyomugyenyi and Kyasimire, 2015; AfrII, 2016).

Feasibility of using local feed resources for pig production. Availability of cassava tubers, sweet potato vines, and rice bran (Table 3) could be attributed to most farmers producing and gathering them for pig feeding (Beyihayo *et al*., 2015; Muhanguzi *et al*., 2012).

Table 2. Feeding, breeding system and use of IMO technology

Variable	No. of respondents (n = 109)	% of respondents
Type of feed		
Local	102	93.6
Commercial	1	0.90
Both	6	5.50
Breeding System		
Natural mating	92	100
Artificial Insemination	0	0.00
Housing pigs		
Yes	65	59.6
No	44	40.4
Use of IMO system (n=65)		
Use IMO	0	0.00
Do not use IMO	65	100

Table 3. Feedstuffs commonly used for pig feeding

Use of feedstuffs (% of respondents)	Gulu	Omoro	Mean
Fresh cassava tubers (Manihot esculenta)	81.1	58.7	70.0
Sweet potato vines	49.5	63.3	56.0
Rice bran	45.0	44.0	44.5
Pigweed (Amaranthus)	40.5	29.3	34.9
Wandering jew (Tradescantia zebrina)	48.6	18.3	33.6
Fresh sweet potato (Ipomoea batatas)	30.6	30.3	30.5
Food residues	22.5	17.4	20.0
Formulated feed	10.8	38.5	24.5
Cassava peels	9.0	16.5	12.7

Most feedstuffs were not uniformly distributed throughout the year (Table 4). Variation in climatic conditions in the region might have been the cause of uneven availability of feeds. Seasonal patterns influence the growth and availability of local feedstuffs (Basalirwa, 1995). To reduce the feed shortage, farmers should preserve feedstuffs in periods of plenty for use when feeds are scarce (Ayano, 2013).

Cost of using producing feeds from commercial and local feedstuffs. The unit cost of making commercial and local feed was Ugx 963 and Ugx 213, respectively (Table 5).

Unit cost of producing a local feed was lower than the cost of a commercial feed by Ugx 749.9 probably attributable to the cheap labour and transport costs, and availability of local feedstuffs. However, there is need to establish the nutrient composition of the formulated commercial and local feeds and subsequently conducting feeding trials to establish their efficacy in pig nutrition. High feed costs in pig production remains a challenge that necessitates the need to utilize less costly local feed resources (Lemke *et al*., 2007).

Table 4. Temporal distribution of local feed resources

Feed	Highest month(s) of availability		Lowest month(s) of availability	
	Gulu	Omoro	Gulu	Omoro
Formulated feed	Jun-Dec	Oct-Dec	Jan-Mar	Jan-Mar
Maize bran	Aug-Oct	Aug-Oct	Jan-April	Jan-Apr
Maize flour	Jul-Oct	Not reported	Not reported	Not reported
Rice bran	Oct-Dec	Nov-Feb	Apr-May	Apr-May
Sunflower seed cake	Jan-Dec	Jan-Dec	None	None
Cassava peels	May-Nov	August	March	Jan-Apr
Fresh cassava	May-Nov	September	Jan-Feb	Jan-Feb
Sweet potato vines	May-Nov	Jul-Nov	Dec-Mar	Jan-Mar
Fresh sweet potato	May-Nov	August	Dec-Mar	Jan-Feb
Food residues	Jan-Dec	September	None	June
Pigweed	May-Oct	Apr-Dec	Dec-Mar	Dec-Mar
Wandering jew	Jun-Oct	Jun-Aug	Jan-Mar	Dec-Apr
Fishmeal	Jan-Dec	Jan-Dec	None	None
Cabbage	June-Dec	Jun-Dec	March-July	Mar-July

Table 5. Unit cost of producing 1kg of a commercial and local feed (Uganda shillings, Ugx)

(a) Unit cost of producing commercial feed			
Feedstuffs	Quantity (kg)	Unit cost	Cost of 1000 kg
Maize bran	74	500	370,000
Soy bean	10	2,500	250,000
Fish meal	5	2,000	100,000
Sunflower	5	2,000	100,000
Lake shell	4	500	20,000
Bone meal	1	700	7,000
Premix	0.5	6,000	30,000
Salt	0.5	1,200	6,000
Labour			30,000
Transport			50,000
Unit cost of commercial feed (Ugx)			963.0
(b) Unit cost of producing local feed			
Sweet potato vines	78.5	83.4	65,469
Fresh cassava	15	195.5	29,325
Rice bran	6.5	170.8	11,102
Hiring a panga	-	1,000	5,000
Digging a pit	1 meter	6,250	6.250
Chopping and ensiling process (labour)		39	39,000
Polythene	15 meters	2,500	37,500
Transport			19,500
Unit cost of commercial feed (Ugx)			213.1

Effectiveness of Indigenous Microorganisms in controlling odour in pig houses. Gram positive and facultative anaerobes were the common microorganisms in IMO solution except *Aspergillus Niger,* and *Aspergillus flavours*, which are obligate aerobes. At pH of 7, humidity of 40% and temperature of 37˚C, molasses medium was more effective in multiplication of IMO than maize bran. Total viable cell counts in molasses were $360x10^2$cfu/gram while pure maize bran had $288x10^2$cfu/gram of the viable cell counts. Respondents who detected smell in deep litter house where IMO solution was not applied were more (p≤0.05) than those where the solution was applied (Table 6). In deep litter house where IMO solution was not applied, most (29.7%) respondents detected strong odour within the house while very few (3.7%) did not detect smell above 40 m from the house. However, in the deep litter house where IMO solution was applied, the majority of respondents detected very weak odour within the pig house (69%) up to 10 m from the house (31%) and none detected odour above 10 m. Therefore, human residences could be located 10 m away from the deep litter pig house when IMO solution is applied and 40 m when the solution is not applied. In deep litter where IMO solution was not applied most (33.7%) respondents detected very strong odour in the morning at temperature of 22.8ºC, pH (7.7) and humidity (61.8%). However, in the deep litter house where IMO solution was applied, most respondents did not detect odour in the house in the morning (65.7%), afternoon (67.7% and evening (64.7%) at different temperatures, pH and humidity. Awareness should be created on the use of IMO in controlling foul smell for pig production.

Table 6. Distance from the deep liter pig house and strong odour detection

Deep litter floor: IMO applied/not applied	Distance (m)	Strong odour detection by respondents (%)	P-value	LSD
IMO applied	0.000	0.000a	0.010	0.020
IMO not applied		3.17b		
IMO applied	10.0	0.000a	0.021	0.025
IMO not applied		12.7b		
IMO applied	20.0	0.00a	0.018	0.014
IMO not applied		19.5b		
IMO applied	30.0	0.000a	0.013	0.011
IMO not applied		17.5b		
IMO applied	40.0	2.17a	0.011	0.010
IMO not applied		31.7b		

ab Means with different superscripts are significantly different at P≤0.05

Performance and pork quality attributes of pigs raised on IMO deep litter floor. The performance of pigs raised on the deep litter with IMO solution applied was not different from that where IMO solution was not applied (Table 7). This indicates that farmers do not need to incur costs and labour involved in the making of IMO solution when they are using deep litter housing system. Other studies showed that pigs reared on fermented deep litter floor had higher weight gains and feed conversion ratios than those reared on concrete floor (Gentry *et al*., 2002; Gentry *et al*., 2002; Johnston and Morrison, 2004; Lebret *et al*., 2006).

Effect of deep litter floor on nutrient composition of pork. Nutrient composition of pork from pigs kept on IMO treated floor did not differ significantly from that of pigs kept on untreated deep litter floor (Table 8). This indicates that IMO application on deep litter floor does not affect the nutrient composition of pork. Crude protein content of 26.8% in the current study was higher than the 23.6% reported by Klimiené *et al*. (2010) when pigs were raised on free range system. Crude fat content of 40.6% in the current study was lower than the 67% reported by Moss *et al*. (1983) when the nutrient composition of fresh retail pork was determined.

Table 7. Effect of deep litter floor on growth performance of pigs

Variables	Litter floor without IMO	Litter floor with IMO	LSD	P-value
Initial weight (kg)	13.7±2.47	15.6±3.70	0.452	0.714
Final weight (kg)	29.1±5.65	39.6±7.95	0.118	0.204
Weekly weight gain(kg)	17.4± 3.59	24.0± 4.78	0.032	0.053
Daily weight gain(g)	0.183± 0.045	0.287± 0.055	0.024	0.051
Feed intake (kg)	8.66± 1.70	9.75± 1.15	0.355	0.623
Feed conversion ratio	0.573± 0.123	0.413± 0.068	0.079	0.082

Note: Feed intake, weight gain and feed conversion ratio of pigs kept on IMO treated and untreated deep litter floor did not differ significantly ($p \geq 0.05$)

Table 8. Effect of deep litter floor on nutrient composition of pork (%)

Variables	Litter floor without IMO	Litter floor with IMO	LSD	P-value
Crude fibre	3.22± 2.12	1.57± 0.873	0.204	0.281
Crude fat	45.8± 10.3	35.5± 9.14	0.236	0.266
Crude protein	26.4± 5.78	27.3± 3.11	0.812	0.833
Ash content	1.36±0.226	1.28±0 .117	0.551	0.601
Dry matter	67.5± 5.99	62.3± 7.70	0.408	0.407
Phosphorus	0.233± 0.021	0.213± 0.021	0.284	0.305

Note: Nutrient composition of pork from pigs kept on IMO treated and untreated deep litter floor did not differ significantly ($p \geq 0.05$)

Effect of deep litter floor on sensory attributes of pork. Sensory preferences (colour, texture, odour and taste) of fried and roasted pork from pigs raised on IMO treated deep litter floor did not vary significantly from those of pigs kept on untreated floor (Table 9). This shows that using IMO on deep litter floor does not affect the eating quality of pork. Other studies also showed that pork eating quality from pigs raised on enriched environments (half concrete area covered with straw and half concrete slats) and conventionally housed pigs (half concrete lying area and half concrete slatted floor) did not differ significantly (Klont *et al*., 2001). Similar results were reported where no much difference was observed in pork sensory quality between pigs housed in deep-litter with wheat straw and those kept in conventional systems with concrete-slatted floor (Johnston and Gentry *et al*., 2002; Morrison, 2004).

Consumer preferences for pork and pork products. At individual level, the majority (55%) of pork consumers were males aged below 35years. Most (75.3%) pork consumers were Roman Catholics living in rural areas (53.9%). Majority (92.6%) of consumers were earning less than Ugx 500,000 with the average income of Ugx 255,000; mostly (73.4%) married, and self-employed (35. 5%). Among the meat products of pork, beef, mutton, goat's meat and chicken, pork was the most preferred and most (30%) consumed. The majority (95.3%) of consumers attributed the consumption frequency to the nice taste of pork. At institutional level, the majority (43%) of consumers were located in urban areas and bought pork from butchers (46%) and farmers (39%). The majority bought fresh pork (73%) and live pigs (45%). Pork ham and ribs were the most preferred parts at both individual and institutional levels. Gender, age, income, marital status, religion, level of education, livelihood source and location influenced ($p \leq 0.05$) the attributes of consumer preferences. Most (96.3%) consumers were willing to pay more for value added pork products such as sausages, bacon and pork chops. Pork freshness, aroma, and taste were the most important attributes for the purchase for the individual and institutional consumers.

Table 9. Effects of deep litter floor on sensory attributes of pork products (% of panel members)

Variables	Litter floor without IMO	Litter floor with IMO	LSD	P-value
Colour of fried pork	3.77±1.31	3.51±1.40	0.308	0.303
Texture of fried pork	4.07±0.942	4.11±1.13	0.861	0.857
Odour of fried pork	4.11±1.13	3.79±1.32	0.182	0.172
Taste of fried pork	4.07±1.08	4.14±0.972	0.711	0.716
Overall acceptability	4.01±1.01	4.00±1.20	0.681	0.672
Colour of roasted pork	3.51±1.40	3.77±1.31	0.296	0.303
Texture of roasted pork	3.47±1.44	3.84±1.22	0.132	0.144
Odour of roasted pork	3.83±1.28	4.05±1.13	0.344	0.355
Taste of roasted pork	4.05±1.13	4.37±0.79	0.068	0.086
Overall acceptability	3.90±0.976	4.09±0.872	0.258	0.268

Note: The sensory preference of fried and roasted pork from pigs reared on IMO treated and untreated deep litter floor did not differ significantly ($p \geq 0.05$)

Perceptions of smallholder pig farmers towards use of artificial insemination

Perceptions of pig farmers to use AI. The perception to use AI was generally positive among male pig farmers as compared to females. The reasons could be that most households were headed by males who in most cases take lead in decision making. Men tend to have better access to production resources due to socio-cultural norms and values which are key in deciding on taking a new technology or innovation. Additionally, men also take lead in enterprises development because they have to earn a living to sustain their families. The current study agrees with those of Abunga *et al*. (2012) and Allotey and Adraki (2018) who independently showed gender had a positive influence on adoption of modern agricultural production technologies. Pig farmers were positive about use of artificial insemination (AI) because most of them had spent reasonable number of years (4years) in pig farming. Experience in pig farming would probably enable pig farmers to make informed decisions regarding the use of AI. Farming experience was reported to influence farmers' choice to innovations (Ndunda and Mungatana, 2013).

Influence of socio-economic factors on pig farmers perceptions to use AI. Perception to use AI was more positive in male pig farmers than the females. The reason could be that most households were headed by males who in most cases took lead in decision makings; men tended to have better access to production resources due to socio-cultural norms and values; men took lead in enterprises development because they had to earn a living to sustain their families. The current study agrees with those of Abunga *et al*. (2012) and Allotey and Adraki (2018) who showed gender had a positive influence on adoption of modern agricultural production technologies. Contact with extension agents reduced perceptions of farmers to AI probably because farmers had been in touch with the extension agents before but were not introduced to AI; extension workers rarely visit the farmers with new technologies such as AI. A study by Abid *et al*. (2015) also showed that agricultural extension service was negatively related to the probability of changing the type of enterprise.

Intensions of pig farmers to use AI. Perceived usefulness of AI had a positive influence on intentions to use AI. For pig farmers to decide to adopt use of AI, they must understand its advantages compared to natural mating. The majority (96%) of the pig farmers had attained formal education, and therefore understood the benefits of AI. Most (70%) were aware of existence of AI and probably its benefits but were only waiting for the opportunity to benefit from the technology. Farmers are most likely to embrace the use of AI if they understand that the technology would enhance pig productivity. In support of the current study, Wong *et al*. (2012) reported that the perceived usefulness was a significant factor influencing the intention to use mobile-shopping. Also, Kwok and Yong (2017) reported that the perceived usefulness had a significant influence on students' intention to use ICT tools.

Socio-economic and information-based factors influencing the innovation behaviour of smallholder pig producers

The influence of socio-economic factors on the innovation behaviour. Promotional activities of pigs and pig products were found to predict farmer innovation process. Farmers who did personal selling, for instance by informing peer farmers about the availability of piglets for sale on the farm, and taking pigs to the market or trading center were found to be 16.6% more explorative, 30.5% more experimental, 42.4% more adaptive and 47.4% more able to improve existing pig rearing techniques. Through personal selling, farmers interact with different people, which enable them to access knowledge, markets, and finance (Chindime *et al*., 2017). This information access through appropriate market searches is likely to offer farmers knowledge of the market outlook prompting them to innovate suitable ways of staying afloat. Education status affected farmers' exploration and experimentation of new pig production and marketing techniques. More educated farmers tend to have a better attitude towards innovation, which enhances their potential to acquire, analyse and utilize information (Tirfe, 2014; Chopeva *et al*., 2015; Chindime *et al*., 2017).

Farmers who had access to extension services were found to be 7.6% more adaptive and 6.6% more able to modify existing practices than those who did not have access extension services. Extension services avail farmers with information and knowledge required to adjust their pig rearing practices to suit their unique farming situations (Kibwika, 2013; Ndunda and Mungatana, 2013; Läpple *et al*., 2015). Farmers with access to credit were 7.5% more adaptive and 9.2% more able to improve existing rearing practices than those who did not have access to credit. Access to credit equips farmers with financial resources to enable them to look for new technologies, purchase farming tools, adapt new practices and modify existing tools and techniques (Ndunda and Mungatana, 2013; Chindime *et al*., 2017).

Farmers who sold pork were found to be 16.8% and 19.4% more able to adapt new practices and modify existing practices, respectively than their peers who sold live pigs. This is attributable to the fact that selling live pigs is the norm in many pig farming households (Tatwangire, 2013). Selling pork probably requires level exposure and awareness, which likely makes the farmers more innovative. Farmers who negotiated the selling price with buyers were found to be 11.6% more likely to modify existing pig rearing practices than those who determined the price by other means such as taking the buyers' price or prevailing market price. Farmers who negotiated prices tended to be more inquisitive, confident and determined, hence propelling them to improve on the existing pig rearing practices.

The information sources that determine differences in farmer innovation behaviour. Farmers who relied on pig traders for market information were found to have a lower likelihood to scan their environments or test new pig rearing practices than those who relied on other sources of information. This was attributed to farmers not trusting the information given by middlemen (Abebe *et al*., 2016; Ajala and Adesehinwa, 2008). Farmers who relied on phones for the information were less adaptive and less able to modify existing practices than those who depended on other sources of information. Most of the pig farmers owning phones use them majorly for conversations and networking with their colleagues (Tatwangire, 2013) other than using them for agricultural related information.

The influence of market information quality on innovation behaviour. Farmers who used market information to make decisions on how to rear pigs tended to have higher innovative activity and creativity which translated into better competitiveness. Previous study by Keh *et al*. (2007) reported that market information utilization was found to affect the performance of small producers through boosting their innovation behaviour. Also, the use of quality market information by farmers to innovate pays off in the long run through enhancing farmers' household incomes and food security (Leitgeb *et al*., 2011). Information utilization predicted up to 64.3% of the variance in farmers' innovation behaviour, which implied that efforts to enhance farmer innovation behaviour needed to focus on improving information utilization by farmers.

Conclusions

Although males as well as females kept pigs, none was using AI, feed formulae from local feedstuffs, and IMO for pig production. The common feedstuffs used for pig feeding were fresh cassava leaves sweet potato vines and rice bran but were not readily available throughout the year. Unit cost of producing a local feed was lower (Ugx 213.1) than that of producing a commercial feed (Ugx 963.0). Most farmers were aware of existence of AI and were positive about its use. Molasses medium was more effective in multiplication of IMO than maize bran where total viable cell counts in molasses were $360x10^2$cfu/gram while that of pure maize bran was $288x10^2$cfu/gram. When IMO solution was applied on deep litter floor, very weak odour was detected up to 10 m from the pig house and no odour was detected above 10 m. However, odour was detected up to 40 meters from the house when IMO was not applied. Pig growth, nutrient composition of pork, back fat thickness and acceptability of roasted and deep fried pork were not affected whether IMO solution was applied or not on deep litter floor. Pork was most consumed meat product where ham and ribs were the most preferred parts. Freshness, aroma and taste were the most important attributes consumers consider when purchasing pork. Farmers who had access to extension services were 7.6% more adaptive and 6.6% more able to modify existing pig production practices. Farmers who used market information to make decisions on how to rear pigs had a higher innovative activity and creativity.

Acknowledgements

The author thanks the Mastercard Foundation through the Regional Universities Forum for Capacity Building in Agriculture (RUFORUM) for funding this project under Grant Number - RU/2017/CARP+/01: Enhancing Pig Production and Marketing for Smallholder Farmers in Northern Uganda. This paper is a contribution to the Fifteenth RUFORUM Annual General Meeting held 2-6 December 2019 in Cape Coast, Ghana.

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