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Assisted Reproductive Technologies for Decision Support in Reproductive Management of Dairy Cattle in Kenya: What are the Prospects? KAPS Study

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ABSTRACT

The human population is expected to double in Africa by 2030 and with it a consequent rise in demand for livestock products. Reproductive technologies improve livestock productivity however, uptake of the technologies has been low in Africa, yet this is where there is a dire need for livestock products as the human population surges. This study aimed to assess knowledge extent and understanding the use of assisted reproductive technologies in decision support for reproductive management of dairy cattle in Kenya. Dairy farmers and veterinary practitioners were interviewed using a questionnaire to obtain relevant data on knowledge, attitude and practices in the use of assisted reproductive technologies in reproductive management in dairy farms. Observable heat signs was the only method used by participants to ascertain estrus in a cow. Artificial insemination technique was adopted by all farmers as the breeding method of choice. The analysis highlighted that the respondents with low levels of formal education had less knowledge on reproductive technologies and displayed risky practices. Overall, a larger proportion of respondents indicated that the assisted reproductive technologies would be important in reproductive management. The relatively low levels of awareness, higher levels of education and a willingness to use the assisted reproductive technologies in reproductive management of dairy cattle strengthen the logic of improving productivity through the application of these assisted reproductive technologies as well as improve levels of awareness of reproductive management practices.

Keywords: attitude, heat detection, knowledge, pregnancy diagnosis, practices, progesterone

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INTRODUCTION

The lifetime production of a dairy cow which includes milk production and calving is directly dependent on the reproductive performance of the herd (Rearte et al., 2018). Detection and correct interpretation of regular estrus, optimal conception rates and early pregnancy diagnosis is critical in attainment of optimum reproductive efficiency (Mičiaková et al., 2018). Over 70% of the dairy output in Kenya is from cattle, of which more than 80% are reared by small-scale farmers resource-poor farmers living on less than a dollar per day (FAO, 2011).

This smallholder production system largely consists of zero grazings where 1 to 3 animals are confined in limited space. This affects the ability of animals to express overt signs of estrus, and in some cases, the signs may not be noticeable. Consequently, the accuracy and efficiency of estrus detection cause a challenge to the attainment of optimum reproductive efficiency in smallholder dairy farms (Fricke et al., 2014; Michaelis et al., 2014). Accurate determination of estrus is therefore central to the optimization of reproductive efficiency, especially where artificial insemination is used. Besides the observation of heat signs, proper timing of AI is another factor that is critical in the determination of fertility at service and is determined by when the animal was confirmed to have been seen in estrus (Posthuma et al., 2009; Fricke et al., 2014). Furthermore, reproductive wastage in dairy farms is contributed by low levels of knowledge of appropriate reproductive management practices as well as a lack of awareness and access to the available assisted reproductive technologies that would enhance reproductive performance.

Due to the impact of low estrus detection rate, delayed pregnancy diagnosis on reproductive performance and the challenges associated with visual estrus detection, technologies have been developed and marketed to farmers. These technologies enhance the detection of estrus by the surveillance of behavior in the absence or in addition to visual observation and also through measurement of progesterone hormone levels for estrus confirmation and pregnancy diagnosis (Fricke et al., 2014). Farmers in developed countries have also embraced the use of pregnancy diagnosis kits that pick out non-pregnant animals before the next expected estrus would inform decision support for remedial action to improve the reproductive performance and consequently target the recommended CI of 12-13 months (Nepal et al., 2019).

These on-farm cost-effective progesterone diagnostic tools to enhance estrus detection, inform appropriate timing of AI and indicate in good time the success or failure of insemination would be useful in reproductive management of cows on smallholder dairy farms. Progesterone detection kits can reduce reproductive inefficiency through increased heat detection rates, early pregnancy diagnosis and detection of subfertility and infertility in the herd (Posthuma-Trumpie et al., 2009, Eastham et al., 2018). However, there is paucity in data of knowledge, attitude, and practices of dairy industry stakeholders in Kenya on the use of assisted reproductive technologies for decision support in reproductive management of dairy cattle.

The present study aimed to therefore to evaluate the knowledge, attitude and practices of dairy industry stakeholders in the utilization of assisted reproductive technologies and for reproductive management of dairy cows in Kenya. This information is essential in future for programs set up to improve the productivity of dairy cattle by improving reproductive performance and application, adoption and uptake of reproductive technologies.

MATERIALS AND METHODS

This was a cross-sectional study using an interview-based survey conducted among smallholder farmers in Nairobi and Kiambu Counties and Animal health practitioners. The selection of the study subjects was purposive based on operationalization convenience although the high density of smallholder dairy farmers in the two counties was considered. Between January and June 2017 dairy farmers and veterinary practitioners were interviewed using a questionnaire to obtain relevant data on knowledge, attitude and practices in relation to the reproductive management aspects and use of assisted reproductive technologies in reproductive management in dairy farms. The dairy farmers interviewed were part of the clientele of the University of Nairobi, Veterinary Hospital.

A structured questionnaire (n=40) with a majority of the questions closed-ended (yes/no response or selection from a list of options n= 32) and some open-ended (n=8) was used to gather the information regarding demographic characteristics, knowledge, attitude and practices relating to routine reproductive management practices of dairy cattle and use of assisted reproductive techniques in farms. The questionnaires were pretested to assess clarity and time requirements and modified in line with feedback from the pre-test. The participants were informed of study objectives and participation was voluntary. Those who did not consent were left out of the study. Short training on the use of the pregnancy/estrus detection kits was done before commencing the interviews.

The reproductive management practices of interest were breeding techniques, heat detection methods and interpretation, artificial insemination timing, timing and method of pregnancy diagnosis, management of postpartum period and management of poor reproductive performance.

Two different questionnaires were made one for farmers and another one for Animal Health Practitioners. The first part of the questionnaire was about the demographic characteristic of the respondents, farm biodata. The second part focused on the knowledge, attitude and practices of aspects of reproductive management and adoption, use of assisted reproductive technologies for decision making support. The sample size was calculated based on the formula by $Z^2\alpha pq/L^2$ (Martin et al., 1987) where the expected proportion was 50%. At least 100 respondents were required for the study.

A total of 127 Animal Health Practitioners and 25 dairy farmers successfully participated in the study. The response rate was 90% for both dairy farmers and Animal Health Practitioners respectively. Incomplete questionnaires were excluded during analysis.

Ethical approval for the study was given by the University of Nairobi Animal care and ethics committee.

Statistical Analysis

Data from the questionnaires were entered in Microsoft Excel software and statistical analysis was done by Stata version 12 (College Station, USA). Initial statistics about the farmers' biodata, demographic characteristics, knowledge, attitude and practices of participants regarding different aspects of reproductive management were done using descriptive means, median and

Table 1. Knowledge of AHP on the use of assisted reproductive technologies in reproductive management of dairy cattle.

	Answers given	**AI Technicians (N=36)**		**AHA (N=28)**		**Vets (N=63)**	
Question							
	Observation of heat signs	36	100%	28	100%	63	100%
Methods of heat detection you are aware of?	Heat detection aids	10	18%	5	18%	30	48%
	Hormone levels	7	20%	5	18%	33	54%
Are you aware of heat detection aids for heat detection?	Yes	11	31%	13	46%	29	46%
	No	25	69%	15	54%	34	54%
	In the morning	36	100%	26	93%	59	94
	In the afternoon	6	16%	5	18%	16	25%
At what time should cows be checked for heat	In the evening	15	42%	8	29%	32	51%
	Mor_aft_eve	6		4		14	
	Clear mucus from the vulva	6	17%	9	32%	33	52%
	Standing to be mounted	28	78%	18	64%	33	52%
How does an inseminator determine if a cow is ready for service?	Palpation of graafian follicle	2	6%	2	7%	13	21%
	Immediately	0	0	0	0	0	0
	45 days	9	25%	10	35%	24	38%
How soon after calving should cows be served?	60 days	13	36%	9	32%	34	54%
	90 days	14	38%	9	32%	5	8%
	1 month	6	17%	9	32%	27	43%
	2 months	4	11%	0	0	16	30%
After how long post insemination is it possible to know the outcome?	3 months	23	64%	17	60%	19	25%
	4 months	3	8%	2	7%	1	2%
Are you aware of kits used for pregnancy diagnosis?	Yes	10	28%	15	54%	34	54%
	No	26	72%	13	46%	29	46%
Are you aware of kits for diagnosis of fertility disorders?	Yes	9	25%	6	21%	18	29%
	No	27	75%	22	79%	45	71%

represented by graphs and charts. Various variables were tested for levels of association with the knowledge, attitude and practices. The level of significance of association was ≤ 0.05 at 95% confidence interval. Chi-square associations between the farmer and farm demographic characteristics and Knowledge, attitude and practices were determined.

RESULTS

Demographic characteristics of respondents

The total of 127 Animal Health Practitioners and 25 dairy farmers participated in the study (Table 1). About 40% of the Animal Health practitioners were between the age of 31-40 years of age of which 87% were males. Veterinary practice is a field commonly dominated by males. Different levels of education were recorded among the practitioners with 33% having a college degree in Veterinary Medicine. Male farmers made up the 56% of the respondents. More than half of the farmers interviewed had attained college level formal education but not in agriculture or livestock farming (56%).

Farm enterprise characteristics

About half (52%) of dairy farmers kept less than 5 animals with the other half divided between those keeping 6-10 animals (40%) and those keeping more than 20 animals (8%). Of the animals kept by the farmers about half of them on each farm were mature breeding cows and the rest heifers and calves. 88% of the farmers indicated to be dairy farmers. Dairy farming contributed up to 50% of the livelihood to most of the farmers (88%) through the sale of live animals and milk. The animals were taken care of by workers (40%), wife (36%) and husband (24%). All the interviewed farmers sought services from Animal Health practitioners.

Knowledge on reproductive management practices

The use of observable signs of heat in estrus detection was known by all the AHP as well as dairy farmers however, most farmers (80%) were not aware of the primary observable sign of heat (standing to be mounted) therefore used other secondary signs to ascertain estrus in the animals. Majority of AHP (62%; 79/127) were aware that standing to be mounted was a

Table 2. Knowledge of dairy farmers reproductive management aspects of dairy cattle.

Question	Response	N=25	
Which methods of breeding are you aware of?	AI	25	100%
	Bull	25	100%
	Embryo transfer	4	16%
Which heat detection methods are you aware of?	Observation of heat signs	25	100%
	Use of heat detection aids	4	16%
	Use of P4 kits	0	0
	Use of teaser animals	0	0
What is duration from heat detection to insemination?	Immediately	0	0
	After 6 hours	2	8%
	After 12 hours	23	92%
How do you determine that a cow is ready to be served?	Increased physical activity and bellowing	25	100%
	Clear mucus discharge from the vulva	25	100%
	Standing to be mounted	16	64%
Are you aware of heat detection aids for heat detection?	Yes	0	0
	No	25	100%
After how long it is possible to know the outcome of an insemination?	After 1 month	9	36%
	After 3 months	16	64%
Methods of pregnancy diagnosis that you are aware of?	Non return to estrus	25	100%
	Rectal palpation	25	100%
	Use of P4 kits	1	4%
	Ultrasonography	10	40%
Are you aware of on-farm kits used for pregnancy diagnosis?	Yes	1	4%
	No	24	96%

primary sign for determination of estrus although, they did not use sign to confirm heat before serving the animals and also they did not confirm at all if the animal is in estrus before AI (Table 1).

Notwithstanding, it was impressive to note that 92% (23/25) of dairy farmers had the knowledge of the AM/PM Rule for insemination time vs the start of heat rule. It was expected that among the animal health practitioners, there would be common knowledge in contrast 17% were not familiar with the insemination timing rule (22/127) were aware. The knowledge about the AM/PM rule of artificial insemination in relation to the start of estrus was higher among AI Technicians ($p < 0.05$) compared to other practitioners, this was expected as they are the major service providers of AI to farmers. Heat detection aids, for example, progesterone (P4)lateral flow field-based kits, pedometers which are not a common phenomenon in developing countries like Kenya were known by a small percentage of participants 35% (45/127) (Table 1).

A number of breeding technologies have been introduced in Kenya with varying adoption and uptake rates for instance, Artificial Insemination was the method of breeding used by all the dairy farmers in the study which implies the successful adoption of this breeding technology in the Kenyan Central Highlands which has a high density of dairy cattle. On the other hand, there were low levels of knowledge on other assisted reproductive technologies such as embryo transfer which was only known by 56 % (71/127) of the AHP, most of whom were Veterinarians ($p<0.0001$) and only 16% of dairy farmers. Optimal calving to conception interval of 45-60 days was known by only 78% (99/127) of AHP and 44% (11/25) of dairy farmers. Pregnancy diagnosis was not a routine practice in the dairy farms, with most farmers indicating that they aware, the earliest pregnancy diagnosis can be done is 3 months (64%;16/25) post AI through rectal palpation. Almost half of AHP (46%; 59/127) indicated that earliest pregnancy diagnosis can be done after 3 months post insemination. Rectal palpation and non-return to estrus were methods of pregnancy diagnosis that were known by all farmers with 40% and 4% of them, also aware of ultrasonography and progesterone (P4) kits respectively (Table 2).

The attitude of Animal Health Practitioners to use assisted reproductive technologies for decision support in dairy farms in reproductive management

After a short training with the participants about the usage of heat and pregnancy detection on-farm progesterone kits, a small percentage of the farmers (11%) indicated that they would use, although a larger proportion believed that observable heat signs are adequate and accurate, others indicated the cost of the kits would deter the adoption. Contrary to heat detection, 88% of the farmers were willing to use progesterone (P4) kits for pregnancy detection to reduce the open days of cows in cases of failed insemination (Figure 1).

Most of the AHP stated that they would use on-farm kits for pregnancy diagnosis if they are available (79%; 101/127) and estrus detection (67%; 85/127). Ninety-one

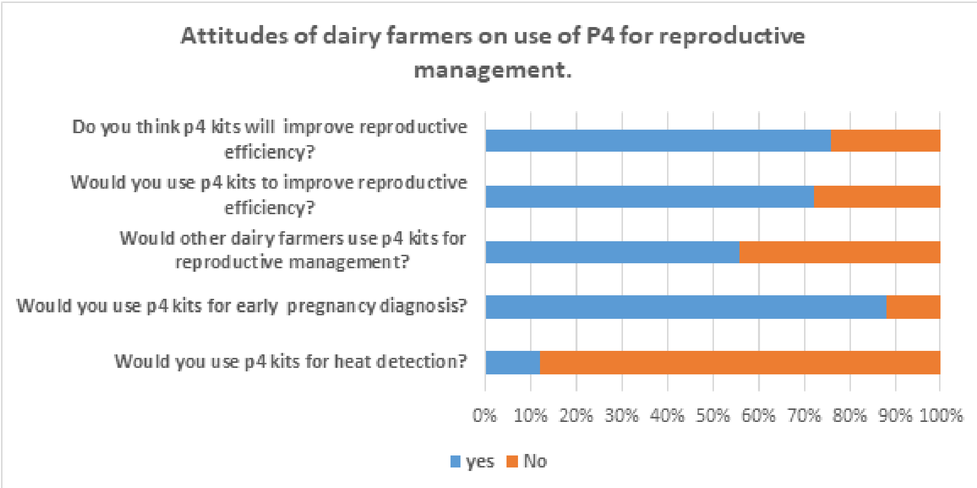

Figure 1. Summary of the attitudes of dairy farmers on the use of ARTs for decision support in reproductive management.

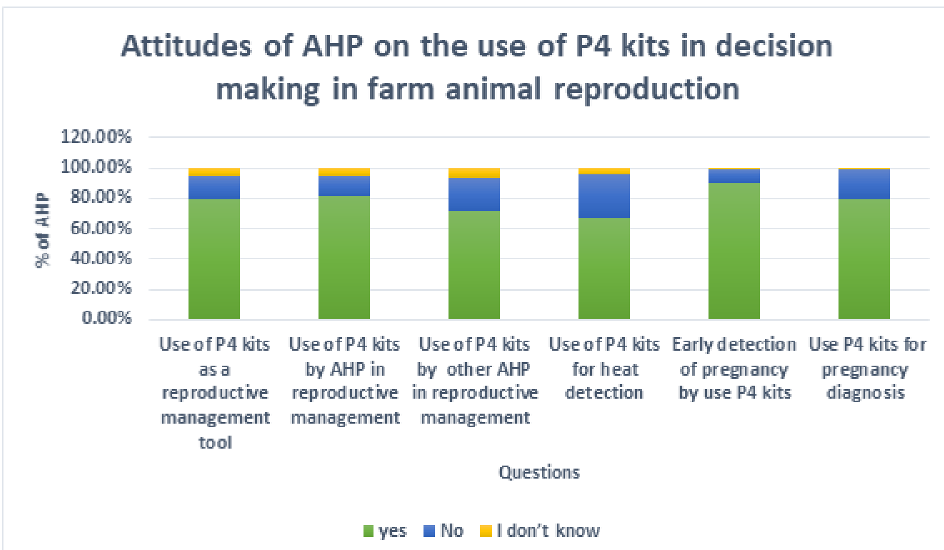

Figure 2. Summary of the attitudes of AHPs on the use of ARTs for decision support in reproductive management.

percent (116/127) of AHP stated that they thought lateral flow assay kits would be important in early pregnancy diagnosis. All the AHP (100%; 127/127) stated that it was important to know the pregnancy status of an animal as soon as possible (Figure 2). Most farmers (88%; 23/25) also indicated that they would have liked to know the outcome of insemination after one month (Figure 1). More Vets as compared to the other practitioners thought that the kits would be important in early pregnancy diagnosis ($p<0.05$).

Generally, the animal health practitioners and farmers agreed that the use of assisted reproductive technologies in various aspects of reproductive management would improve reproductive efficiency in dairy farms**.**

Most of the AHP (82%; 104/127) indicated that they would use the ARTS in reproductive management of dairy cattle, the majority of those being Vets ($p<0.05$) (Figure 2). The inaccuracy of technologies, high cost was indicated as the reason for unwillingness to use them for reproductive management by 19% (3/16) of the respondents who indicated they would not use them.

Practices of AHP and dairy farmers on the use of ARTs for reproductive management

Artificial insemination was the only breeding technology used by all the farmers following heat detection by observable signs of estrus in the cows done by farmers. The signs used by all farmers included: the restlessness

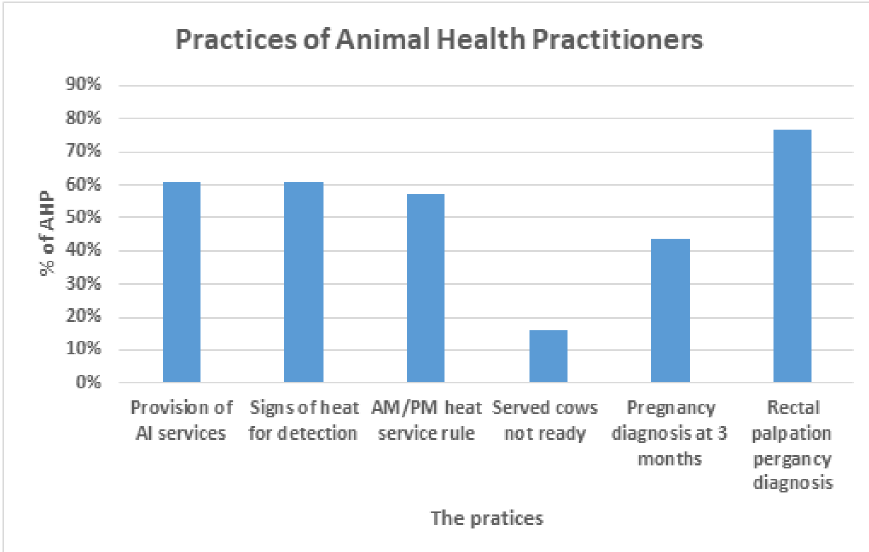

Figure 3. Summary of the practices carried out by majority of AHPs.

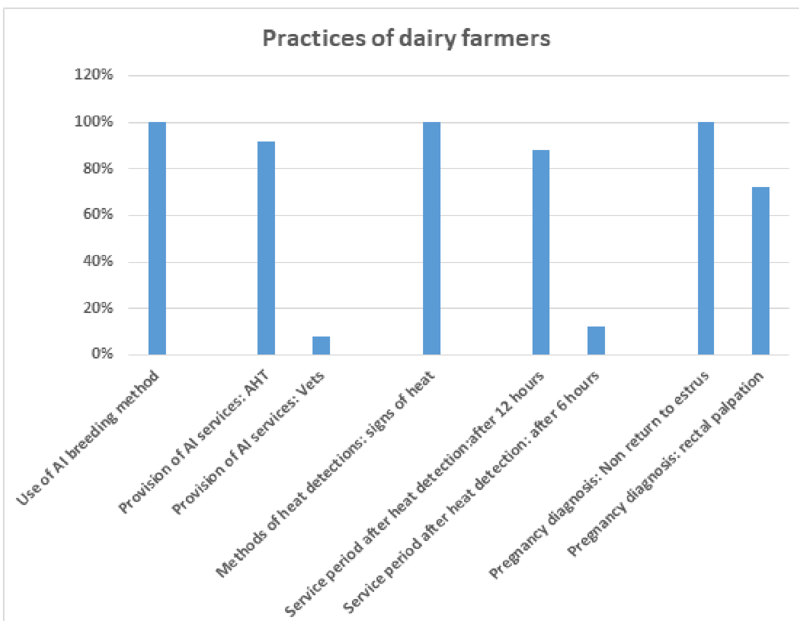

Figure 4. Summary of reproductive management practices of dairy farmers.

of the animal, frequent bellowing and decreased milk production whereas others used other signs in addition to these, 52% (13/25) of farmers used standing to be mounted and 58% (14/25) clear vulval mucus discharge as the signs that the cow was on heat.

More than half of the practitioners (58%;74/127) used the AM-PM rule for determination of the time for insemination as supported by the response of the majority of farmers (88%; 22/25) who reported that their cows are usually served 12 hours after the start of heat(Figure 3). At least 26% (20/77) of the AHP had served a cow not in standing estrus and 80% (16/20) of them attributed this to reliance on farmers on when heat was observed and that by the time they realized the cow was not in standing estrus they had already thawed the semen (Figure 3).

Eighty-eight percent of dairy farmers usually called AHP 3 months after insemination to confirm pregnancy through rectal palpation while the rest waited until the inseminated animal returned to heat (Figure 3). All farmers assumed that the inseminated animals were pregnant if they did not return to estrus the following month, whereas a small percentage (16%) also indicated that if an inseminated animal had a bloody discharge from the vulva within 7 days after estrus, insemination was assumed to have failed (Figure 4).

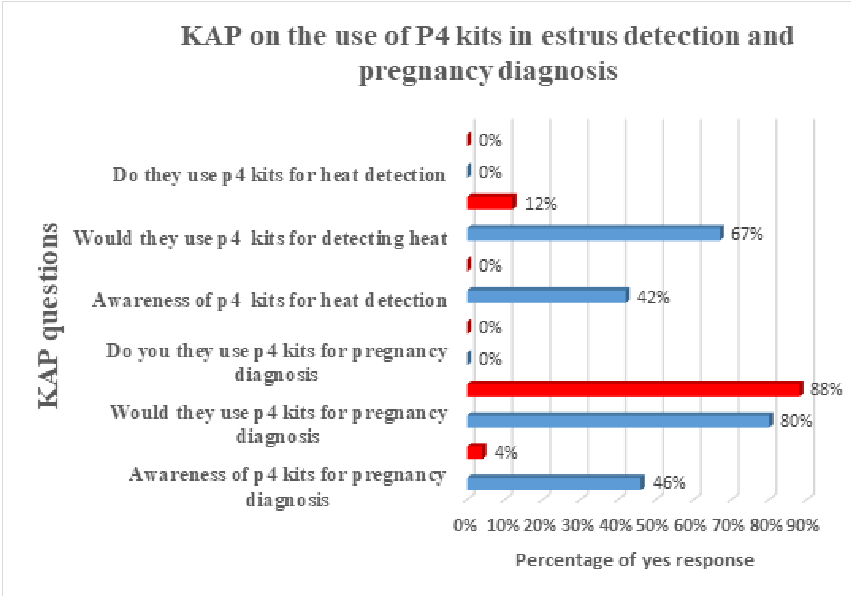

Figure 5. Summary of the knowledge, attitude and practices of Animal Health Practitioners and dairy farmers AHPs and dairy farmers on the use of for estrus detection and pregnancy diagnosis aids.

Dairy farmers listed the parameters they used to measure reproductive efficiency in their farms and the values they considered optimum. These included: optimum calving to conception interval of 90 days (44%; 11/25), 2 services per conception (24%; 6/25), 50% of breeding females at any one time pregnant (16%; 4/25) and an optimum age at first calving of 3 years (16%; 4/25) (Figure 4).

Comparison of the knowledge attitude and practices of AHPs and dairy farmers on the use of estrus detection and pregnancy diagnosis aids

None of the AHPs nor farmers were using any kits in heat detection or pregnancy diagnosis, although some of them are aware of their existence. None of the AHPs used P4 kits for pregnancy diagnosis, although 46% were aware (Figure 5).

DISCUSSION

The adoption of diagnostic tools in reproductive management decisions in dairy cattle depends greatly on the willingness of the dairy industry stakeholders to acquire and use the tools. It was, therefore, paramount to assess the knowledge, attitude and practices (KAP) of Animal Health Practitioners and dairy farmers on the use of ART's for decision support in reproductive management. Such information may help in the identification of knowledge gaps that need to be filled, behavioral patterns on the use of diagnostics tools and dairy reproductive management practices that would influence the adoption of the ART's technology. Based on the information from the KAP, both the farmers and AHP were knowledgeable about appropriate reproductive management practices although, they could not apply some of them due to various challenges mainly, the financial cost involved or the nature of smallholder systems in which they kept 1-3 animals thus the capital investment is less, dairy farming considered a part-time venture. However, their knowledge and practices of assisted reproductive technologies other than AI were limited.

These dairy industry stakeholders had adequate knowledge of the observable signs that animals on heat exhibit. Nevertheless, only about half of the farmers and AHP used the standing to be mounted as a primary sign to determine if an animal was in estrus. The challenge of dairy farmers' not using standing to be mounted as the primary sign of heat has also been reported previously (Eklundh, 2013; Michaelis et al.,2014). In the current study, failure of observation of mounting behavior was speculated to be due to the intensive nature of small scale holder dairy systems which is common in Kenya in which the animals are confined each in its stall with limited space, therefore this compromises the natural expression of heat signs (Staal et al., 2008; Muia et al., 2011). The use of rapid heat detection kits together with the signs of heat will help increase the heat detection efficiency and accuracy in these production systems. Additionally, the knowledge and practices of the recommended times for checking heat in a herd which is at least three times a day for 30 minutes each day (Negussie et al., 2002; Mičiaková et al., 2018) was limited among the dairy farmers. This was thought to be due to the inability of the farmers to partition the requisite labor for heat detection due to cost limitations. Majority of AHP and farmers also knew about the AM/PM rule of serving animals in relation to the start of estrus as documented by researchers (Fodor et al., 2019). However, definitive determination of the time of the start of estrus was the main challenge that hindered the use of this AM/PM rule Animals that start estrus late in the evening or at night may be reported the next day by farmers to have started heat that same morning. Such information results in the timing of AI being inaccurate. Consequently, the adoption of P4 kits for estrus detection would enable confirmation of the estrus status of the animals presented for AI. The farmers themselves may also not be able to invest that required time in heat detection as dairying was not the primary activity for majority of them as seen in the study, in addition to many being away from the farm for a significant amount of time during the day attending to other activities. Assisted reproductive technologies for instance field-based heat detection kits whose diagnosis is based on the levels of progesterone hormone in blood/milk would sort out the inaccurate heat detection and the lack of adequate labor to examine the animals for heat.

Artificial insemination was being used for breeding widely as indicated by a large number of AHP offering these services across the country and also from the practices of dairy farmers. In contrast, the knowledge and adoption for other technologies such as embryo transfer (ET), Superovulation, ovulation synchronization, pregnancy diagnosis kits were very low. Artificial insemination has been documented as the most successful and widely adopted assisted reproductive technology (Rodriguez-Martinez, 2012) as also reported in the current study. The dairy industry in Kenya still has some way to go in terms of improvement of the Country genetic base as the industry depends heavily on imported bull semen. Currently, AI remains the most viable and affordable breeding technology to achieve this. Although the dairy sector is undergoing rapid growth and transformation, adoption of other technologies such as ET remains low and expensive.

Animal Health Practitioners were knowledgeable that the estrus status of the cow and timing of AI were critical determinants of the success of AI. The conception rates are usually high when these two factors are accurate, and this could be increased further by the use of rapid P4 kits which would be used to accurately determine estrus status before AI. Determination of standing estrus status by use of P4 kits would also ensure that only animals that are in estrus are served, thereby reducing the cost incurred by farmers due to repeated inseminations caused by serving animals that are not in standing estrus as reported by some AHP.

Calving to conception interval is a parameter of importance in the achievement of the optimum calving interval of 365-400 days (Hernandez et al., 2001) of which a larger proportion of both dairy farmers and AHP were knowledgeable about. Ninety days is the recommended cut off point if one is to achieve a CI of 365 days. Otherwise, breeding animals earlier than this would be the desirable practice. Delayed resumption of ovarian cyclicity and suboptimal estrus detection has been listed as the main challenges causing long calving to conception intervals (Souames et al., 2018). This can be overcome by the use of progesterone detecting kits that would determine circulating progesterone levels which could be used as an indicator of resumed cyclicity in the open cows.

Pregnancy diagnosis to determine pregnancy which is the epitome of the reproductive cycle was not a routine monthly practice in all the farms. Majority of AHP only did pregnancy diagnosis through rectal palpation when requested by farmers after 3 months post insemination. Clearly, these are high-risk behaviors that point to reproductive inefficiency and wastages within the dairy farms in Kenya. Compared to dairy farms in developed countries, many have embraced estrus synchronization and timed artificial insemination, followed by pregnancy diagnosis 30 days post insemination (Bekele et al., 2016; Rodriguez-Martinez et al., 2012). For early pregnancy diagnosis, ultrasonography has been used in large to medium farms due cost implication of the sonography. Another technology utilized is the immunoassay kits that detect the status of pregnancy by detecting progesterone hormone levels (hormone of pregnancy) that indicates pregnancy status at day 25 post AI (Nepal et al., 2019). Adoption, uptake and use of such kits in pregnancy diagnosis for the participants was assessed and very few had knowledge on their existence let alone their use. Progesterone immunoassay kits P4 kits are a new technology in Kenya as indicated by the low levels of knowledge as well as the fact that none of the dairy industry stakeholders was presently using them in reproductive management of dairy cattle. However, a larger proportion of both the dairy farmers and AHP indicated that they would be willing to use these rapid kits in reproductive management of dairy cattle if they were cost-effective and accurate. The willingness of the dairy industry stakeholders to use heat detection kits, pregnancy diagnosis kits and other assisted reproductive technologies and high levels of education of the dairy industry stakeholders are indicators that if the technologies are accessible, cost-effective, easy to use the adoption rates will be high. With more training and awareness of the use and importance of these kits, their use for decision support in reproductive management of dairy cattle may increase.

CONCLUSION

According to the study findings, the farmers in the study exhibited risky behaviours that predispose to reproductive efficiency in dairy farms. Therefore, farmer education by relevant animal health service providers on reproductive management practices would go a long way in minimizing reproductive wastage. Stakeholders in the dairy cattle industry are willing to adopt decision support tools such as on farm lateral flow kits for pregnancy for reproductive management of their farms therefore it is the right time for service providers in the animal health sector to think about sustainable provision of the heat detection aids, heat detection kits, pregnancy detection kits and any other assisted reproductive technologies that would be cost effective and beneficial to the dairy farmers.

REFERENCES

Bekele N, Mekonnen A, Nejash A, Wahid AM (2016).Pregnancy Diagnosis in Cattle for Fertility Management: A Review. Global Veterinaria 16(5):355-364.

Eklundh C (2013). The use of artificial insemination in dairy farms Peri-urban and Urban areas of Uganda: A study of knowledge, attitude and practices. Swedish University of Agricultural Sciences. http://epsilon.slu.se(Accessed 20 May 2016).

Eastham NT, Coates A, Cripps P, Richardson H, Smith R, Oikonomou G (2018). Associations between age at first calving and subsequent lactation performance in UK Holstein and Holstein-Friesian dairy cows. PLoS One, 13(6):1-13.

FAO (2011). Dairy development in Kenya. Food and Agriculture Organization. www.fao.org/docrep/013/.../al745e00.pdf(Accessed on 20 March 2017).

Fricke PM, Carvalho PD, Giordano JO, Valenza A, Lopes G, Amundson MC (2014). Expression and detection of estrus in dairy cows: the role of new technologies. Animal, 8.134–143.

Fodor István, László Ozsvá (2019). Estrus detection and its impact on reproductive and economic performance in large dairy herds. AWETH Journal 15 (1): 18-28.

Hernandez J, Shearer JK, Webb DW (2001). Effect of lameness on the calving to conception interval in dairy cows. Journal of the American Veterinary Medical Association. 218: 1611-1614.

Negussie F, Kassa T, Tibbo M (2002). Behavioral and physical signs associated with estrus and some aspect of reproductive performance in Fogera cows and heifers. Tropical Animal Health Production 34: 319-328.

Martin SW, Meek AH and Willeberg P(1987): Veterinary Epidemiology, Principles and Methods. Lowa State University Press, Ames, IA, pp.63-71.

Mičiaková M, Strapák P, Szencziova I, Strapáková E, Hanušovský Ondrej. (2018). Several Methods of Estrus Detection in Cattle Dams: A Review. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 66(2): 619-625

Michaelis I, Burfeind O, Heuwieser W (2014). Evaluation of estrous detection in dairy cattle comparing an automated activity monitoring system to visual observation. Reprod.Domest.Anim., 49.621-628.

Muia JMK, Kariuki JN, Mbugua PN, Gachuiri CK, Lukibisi LB, Ayako WO, Ngunjiri WV (2011). Smallholder dairy production in high altitude Nyandarua milk-shed in Kenya: Status, challenges and opportunities. Journal of Livestock Research for Rural Development 23: 108-120.

Nepal S, Subedi D, Kaphle K (2019). Pregnancy Diagnosis with Progesterone ELISA Kit in Farm Animals, Its Accuracy and Application. Nepalese Veterinary Journal, 36: 111-117.

Posthuma-Trumpie GA, Van-Amerongen A, Korf J, Van-Berkel WJH (2009). Lateral Flow Immunoassay for progesterone detection. Journal of Biotechnology 27: 652-654.

Staal SJ, Pratt AN, Jabbar M (2008). Dairy Development for the Resource-Poor Part 1: A Comparison of Dairy Policies and Development in South Asia and East Africa. PPLPI. Working Paper No. 44 International Livestock Research Institute.

Souames S, Abdelli A, Berrama Z (2018). Factors associated with abnormal resumption of ovarian activity after calving of Holstein-Friesian cows reared in northern Algeria. Livestock Research for Rural Development. (30)52: 39-43.

Rearte SJ, LeBlanc SG, Corva RL, De la Sota IM, Lacau-Mengido, Giuliodori MJ (2018). Effect of milk production on reproductive performance in dairy herds. Journal of Dairy Science, 101(8):7575–7584.

Rodriguez-Martinez H (2012). Assisted reproductive techniques for cattle breeding in developing countries: a critical appraisal of their value and limitations. Reproduction in Domestic Animals Journal 47: 21-26.