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Acquisition of Goat and Sheep Farming Knowledge and Artificial Insemination Technology of Nanomaterial-Assisted Semen Sexing for Farmers in Wagir District, Malang Regency

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Abstract In accordance with the Malang Regency Regional Development Plan, Wagir District is one of the Livestock Centre's in Malang Regency because of its higher population of goats and sheep. However, the lack of goat and sheep farming knowledge as well as lack numbers of superior quality and quantity of lambs become main problems for realizing that plan. Therefore, a four-helix joint program was conducted through the collaboration of farmer communities, universities, industries, and local government to solve those problems. The community empowerment was aimed to improve the goat and sheep husbandry knowledges and farming skills as well as to train farmers in applying the artificial insemination technology with nanomaterial-assisted semen sexing to improve the availability of superior lambs of goats and sheep and sustaining the quantity and quality of goats and sheep in Wagir District of Malang Regency. The approach of participatory action and learning system was conducted through the community empowerment program, including valuable activities, namely focus group discussion, training, and direct practice, mentoring and field monitoring in 12 villages. The results of this program showed that the farmer awareness, knowledge, and skills on practicing good farming of goat and sheep as well as the application of the artificial insemination technology with nanomaterial-assisted semen sexing increased significantly from 20% to 90%. The social and economic impacts of the application of artificial insemination technology of nanomaterial-assisted sexing semen are the significant increase of goats and sheep farming productivity and the strengthening of livestock business management.

1. INTRODUCTION

Wagir District is one of the districts in Malang Regency which consists of 12 villages with a high population of goats and sheep (Kusumawati, Zaini, Sarwoko, Mahmud, Ramayanti, et al., 2024). The goat population in Wagir

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District amounts to 4,113 while the sheep population stands at 2,661 (Kusumawati, Zaini, Sarwoko, Mahmud, & Ramayanti, 2024). In accordance with the Medium-Term Development Plan of Malang Regency for 2021-2026 (Pemerintah Kabupaten Malang, 2021), Wagir District will be developed into one of the centers for goat and sheep livestock in Malang Regency.

Currently, the market demand for goats and sheep is quite high along with the economic recovery of the community after Covid-19. Therefore, it is necessary to increase the population and quality of goats and sheep. One way to increase the population of goats and sheep is by using artificial insemination (AI) technology (Camacho et al., 2017; Kusumawati, Ikhwan, et al., 2024; Murtaza et al., 2020; Nuraini et al., 2021; Prihatin et al., 2021) for sexing semen (Kusumawati et al., 2019). Based on previous research findings (Prihatin & Amam, 2022), AI in goats provided the same opportunity to produce proliferation and sex ratio as well as natural mating, where there was no significant difference (P>0.05) between AI and natural mating in terms of the type of birth and sex of goats per birth.

AI still has shortcomings in terms of effectiveness and costs because it uses cryopreservation that requires a freezing step using liquid nitrogen at a high cost. The development is urgently needed for better techniques and biomaterials that support AI, not only low cost but also environmentally friendly and contribute to the development of sustainable food for all people leading to human and animal welfare (Kusumawati & Karyasa, 2022). It is necessary to develop new biomaterials as new procedures to improve the quality of preserved spermatozoa and reduce costs and technologies that are suitable for livestock farming. For example, it has been reported that AI for livestock farming still has problems, especially its effectiveness (Ali et al., 2019). The results of our current research, as intended in the brief review (Karyasa, 2021; Karyasa & Kusumawati, 2024; Kusumawati, 2021), are to develop biomaterials to support artificial insemination based on local raw materials. For example, silica biomaterials are derived from rice husks and hydroxyapatite phosphate from animal bone waste. These biomaterials are used to produce ampoules that have humidity and temperature sensor properties in the form of silica gel layers to develop new ambient temperature spermatozoa preservation and new extender formulas to improve semen quality. The use of AI technology for sexing semen assisted by nanomaterials has been proven to be successful, moreover it can produce the expected sex of offspring (Kusumawati, Karyasa, et al., 2024).

Innovation in AI technology of semen sexing (Kusumawati et al., 2019; Susilawati et al., 2021) and nanomaterial-assisted breeding can replace dependence on imported straws made of plastics and quite expensively liquid nitrogen. The innovative nanomaterial straws can change their color when the quality of sperms in those straws decrease, besides that, the straws can also be stored at room temperature and 5ºC. The innovation in AI technology with semen sexing and nanomaterial-assisted breeding is expected to be able to solve the problem of low quality of sheep and goat lambs which has an impact on low productivity of sheep and goat farms. Success in AI is largely determined by the quality of the stored semen, therefore the storage device, especially straws or ampoules, is an important part that cannot be separated from the overall semen cryopreservation technology. Straw materials are generally made of thermoplastic materials that are very susceptible to damage during low temperature cooling and during semen thawing after being stored at low temperatures due to biotic and abiotic stress from spermatozoa in the cooled semen. Plastic materials tend to be susceptible to producing microplastics during high temperature cooling which can poison or damage the ability of spermatozoa cells. Straws or semen storage ampoules made of nanomaterials are safe and resistant to cold temperatures and have the ability to absorb water (secretions from damaged cells during storage or during thawing and transfer to animals subjected to AI) by providing color changes so that if damage to semen or spermatozoa in the straw or ampoule can be detected. This invention contributes to increasing the efficiency of energy use and reducing the use of expensive and environmentally unfriendly materials that contribute to the development of semen storage technology for animal breeding and breeding that contributes to safer, healthier, more efficient and environmentally friendly livestock (Karyasa & Kusumawati, 2024; Kusumawati, 2021; Kusumawati, Karyasa, et al., 2024; Kusumawati & Karyasa, 2022; Kusumawati & Karyasa, 2024). Utilization of rice farming waste, namely rice husk ash as a source of silica and cow bone waste as a source of calcium phosphate for the manufacture of nano calcium silico-phosphate ampoules and nano calcium phosphate powder which can provide an added values to rice farming waste, for instance rice husk ashes and cattle farming, especially cow bone wastes (Karyasa, 2021).

Based on the results of field monitoring, data showed that the goats and sheep farmers in 12 villages in Wagir District still have a low knowledge on AI technology and breeding management so that the livestock productivity is still low because of the low quality of superior parent stock. Therefore, it is necessary to transfer the current advanced AI knowledge and technology for sexing semen assisted by nanomaterials to increase livestock productivity to the targeted goats and sheep farmers.

2. METHOD

The community empowerment activities were carried out from June 2023 to 2024 in Wagir District, Malang Regency, East Java, which was attended by 48 participants who were called as the targeted goats and sheep farmers, comprising of 36 representative farmers from 319 farmers and 12 village officials from 12 villages in Wagir District. Each village was represented by 3 farmers. Data were processed and combined from randomly selected samples in representing the population (Kusumawati, Zaini, Sarwoko,

Mahmud, Ramayanti, et al., 2024). The community empowerment activities were conducted by applying the approach of participatory action and learning system (PALS) adopted previously reported (Karyasa et al., 2021).

The activity began with an offline Focus Group Discussion (FGD) held at the Malang Regency Regent's Office which was attended by 12 representatives of the Village, PT KTHR, BUMDesMa Wagir Berkah and the community service team and the Malang Regency Regional Research and Innovation Agency. The next activity was training and direct practice in the use of artificial insemination technology using nanomaterial-assisted sexing semen. The training activity was carried out at the BUMDesMa Wagir Berkah Office which was attended by 48 participants from 12 villages. Meanwhile, the practice of artificial insemination using nanomaterial-assisted sexing semen was carried out at PT KTHR Indonesia. In this training activity, a pre-test and post-test were also carried out to evaluate the activity. The impact of the community service activity was carried out using a survey method before and after the activity took place with the following indicators: (a) level of participation of target partners, (b) level of satisfaction of target partners towards the implementation of community service activities (Hananditya et al., 2021), (c) commitment, knowledge and skills of partners in carrying out these activities effectively. The last stage is mentoring and field monitoring of the results of the transfer of artificial insemination technology using nanomaterial-assisted sexing semen in 12 villages. This community service activity also involved 5 students from the Faculty of Animal Husbandry, Universitas PGRI Kanjuruhan Malang, 1 student from the Laboratory High School, Universitas Negeri Malang, and supported by the Regional Research and Innovation Agency of Malang Regency, 2 servants from Universiti Sultan Zainal Abidin Malaysia. The collected qualitative and quantitative data were analyzed descriptively and interpreted deeply.

3. RESULT AND DISCUSSION

The Focus Group Discussion (FGD) activity, held at the Malang Regency Regent's Office, resulted in a consensus that all Wagir Village Heads and the Malang Regency government fully support the community service initiative, "Empowerment of Regional Superior Product Business Partners, Ministry of Education, Culture, Research, and Technology." This initiative aims to establish Wagir District as one of the key Goat and Sheep Centers. All village heads in Wagir District also assisted and monitored the results of activities in their respective villages and allocated funds from village food security, namely 20% of village funds. PT KTHR Indonesia provided support in the form of livestock management assistance. BUMDesMa Wagir Berkah provided assistance for meeting facilities and marketing of livestock products. The Malang Regency Regional Research and Innovation Agency provided assistance, strengthening and full support to establish goat and sheep center.

In this FGD activity, the schedule for implementing training activities and practicing the application of AI technology using nanomaterial-assisted semen sexing was also agreed upon. All invited participants to the FGD activity were present comprising 12 representatives of the Village, PT KTHR, BUMDesMa Wagir Berkah and the community service team and the Regional Research and Innovation Agency of Malang Regency. The number of FGD participants was in accordance with the ideal FGD standards (Fazeeha Azmi, 2023). The FGD resulted in a strong commitment among participants and stakeholders to enhance the knowledge and skills of goat and sheep farmers in breeding, animal care, and farm management.

Figure 1 . Activities of: (a) Training; (b) Implementation

To boost the productivity of goat and sheep farming, the community empowerment activities were extended to include training and practical sessions on AI technology utilizing nanomaterial-assisted semen sexing. The AI technology using nanomaterial-assisted semen sexing was an application of a granted patent IDP000092611 (Kusumawati & Karyasa, 2024). AI technology using nanomaterial ampoules can overcome the problem of liquid nitrogen scarcity for frozen semen because by using nanomaterial ampoules, the semen could be stored for more than 5 days without using liquid nitrogen. In addition, the AI technology with semen sexing utilized in the activities was an application of the granted patent IDP000078015 (Susilawati et al., 2021). This semen sexing technology enables the production of offspring with the farmers' desired gender. The results of the community service activities demonstrated the successful implementation of artificial insemination using nanomaterial-assisted sexing semen, with over 60% of the procedures achieving outcomes categorized as successful. Additionally, the goat and sheep population showed a significant increase, rising from 1,450 to 3,326. Training activities (Figure 1 (a)),

implementation (Figure 1 (b)) and mentoring of the AI technology using nanomaterial-assisted sexing semen were carried out at PT KTHR Indonesia and BUMDesMa Wagir Berkah.

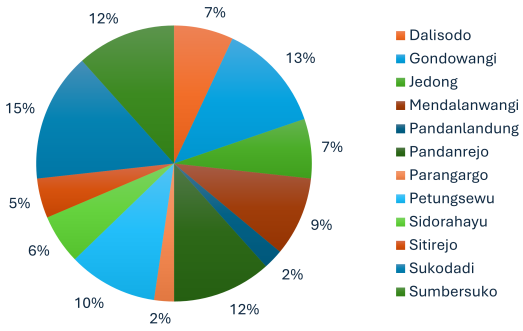

Figure 2 . The distribution of goats (86 heads) in 12 villages in Wagir District which were successfully conducted AI in 2023

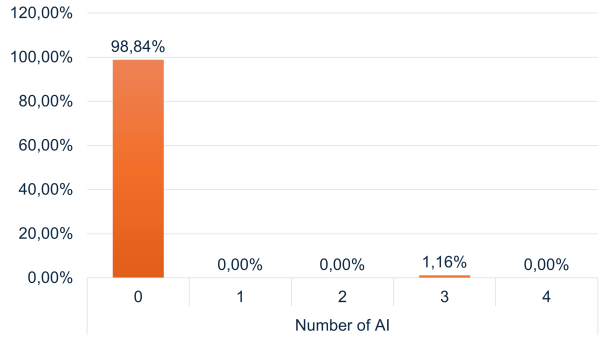

Figure 3 . The distribution of goat livestock conditions when going to be inbred

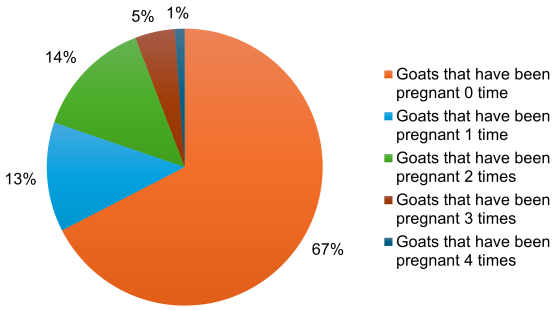

Figure 4 . The distribution of goats that were/were never pregnant during AI

The success rate of AI is reviewed from (i) the condition of livestock before AI, (ii) the number of livestock successfully pregnant from the number of livestock that were AI, (iii) the number of pregnant livestock that successfully gave birth, (iv) the number of goats born, and (v) the sex of livestock that were born. The survey related to the condition of livestock before AI is presented as follows. The number of livestock samples that were successfully AI in 12 villages in the 2023 program related to 120 goats with the preparation of Wagir District as the Malang Goat-Sheep Center was 86 goats (71.7%).

The number of goats that were successfully inseminated in 12 villages in Wagir District in 2023 was 86 (Figure 2) where the largest number was in Sukodadi Village (13) and the smallest number was in Pandanlandung Village and Parangargo Village, each with 2. When inseminated, 98.84% (85) of goats had never been inseminated, only 1.16% (1) had been inseminated before (Figure 3). When inseminated, the condition of livestock that had been pregnant and had never been pregnant is depicted in Figure 4 where 58 goats (67%) had never been pregnant, 11 (13%) had been pregnant once, 12 (14%) had been pregnant twice, 4 (5%) had been pregnant 3 times and 1 (1%) had been pregnant 4 times.

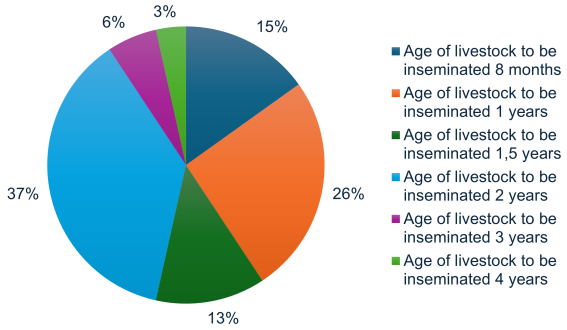

Figure 5 . The distribution of goat ages during AI

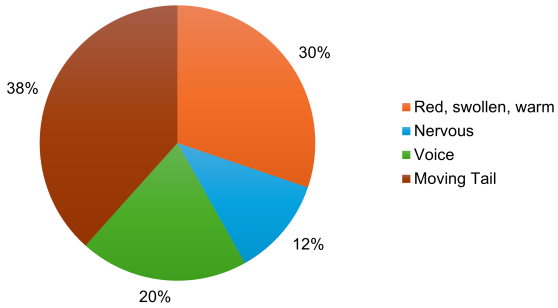

Figure 6 . The distribution of detection of goats' lust

Figure 5 illustrates that the majority of goats undergoing artificial insemination (AI) were 2 years old (37%), followed by those aged 1 year (26%), 8 months (15%), and 1.5 years (13%), while only 9% were 3 or 4 years old. This distribution indicates that the ideal age for goats to undergo AI is 2 years. Additionally, the success of AI is highly dependent on the farmers' ability to accurately recognize the estrus condition of the goats. The estrus condition recognized by farmers as a sign of the right time for AI is presented in Figure 6, namely the tail moving (41%), 3A (abang = red vulva, abuh = enlarged vulva, and anget = warm vulva felt) as much as 24%, 24% recognized by the sound of the goat, and the goat was restless as much as 11%. It is more effective if these four characteristics are recognized well, because accurate observation of estrus is one of the determining factors for the success of AI (Kusumawati, Ikhwan, et al., 2024). Furthermore, the success rate of AI is seen from the percentage of pregnancy

from the number of goats that were AI-trained (Figure 7) and the percentage of normal births from the number of pregnant goats from AI-trained (Figure 8) as well as the comparison of the number of goats born normally with the number of pregnant goats and the number of goats that were AI-trained (Figure 9) and the percentage of the success rate of AI is reviewed from the number of pregnancies and the number of lambs born normally (Figure 10). The average percentage of pregnancy from goats that were AI-trained was 64% (55 pregnant goats from 86 goats that were AI-trained). Out of 55 pregnant goats, 52 successfully gave birth normally, accounting for 95%, while 3 goats miscarried, representing 5%. The total number of kids born from the 52 goats that delivered normally was 54, indicating a birth rate of 104%. Among these, 50 goats (96%) gave birth to a single kid each, while 2 goats (4%) delivered twins. One key factor influencing the success of pregnancy is effective livestock management (Kusumawati, Ikhwan, et al., 2024).

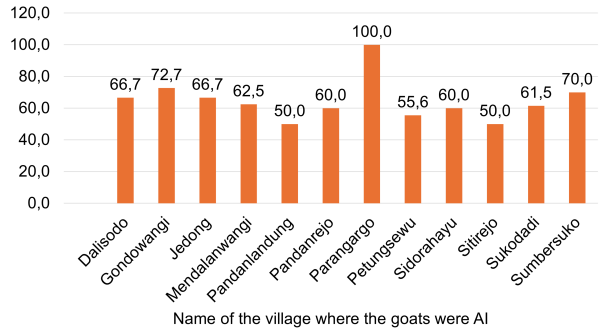

Figure 7 . The percentages of pregnancy in goats after AI

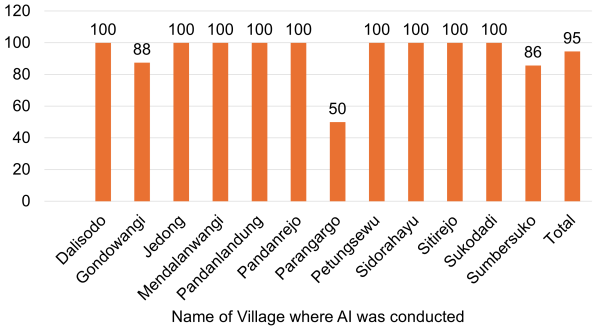

Figure 8 . The percentages of normal births from the number of pregnant goats resulting from AI

Therefore, based on the data in Figure 2 to Figure 10, it can be stated that (i) the condition of the livestock before being inseminated is classified as healthy with 99% of the goats being inseminated for the first time or having never been inseminated before and the majority (67%) having never been pregnant before or being virgin goats, (ii) the number of livestock that successfully became pregnant from the total number of livestock that were inseminated was 61% or 55 pregnant goats from 86 goats that were inseminated, (iii) the number of pregnant livestock that successfully gave birth was 52 goats giving birth normally from 55 pregnant goats or 95% while 3 pregnant goats miscarried (5%), (iv) the number of lambs born was 54 lambs (cempe) from 55 pregnant goats (98%) or from 52 pregnant goats that gave birth normally (102%) which means that there were goats that gave birth to more than 1 kid or 50 pregnant goats (96%) gave birth to 1 kid and 2 pregnant goats (4%) each giving birth to 2 calves each, and (v) the sex of the livestock born was 35 male calves (65%) and 19 female calves (35%) and were calves according to

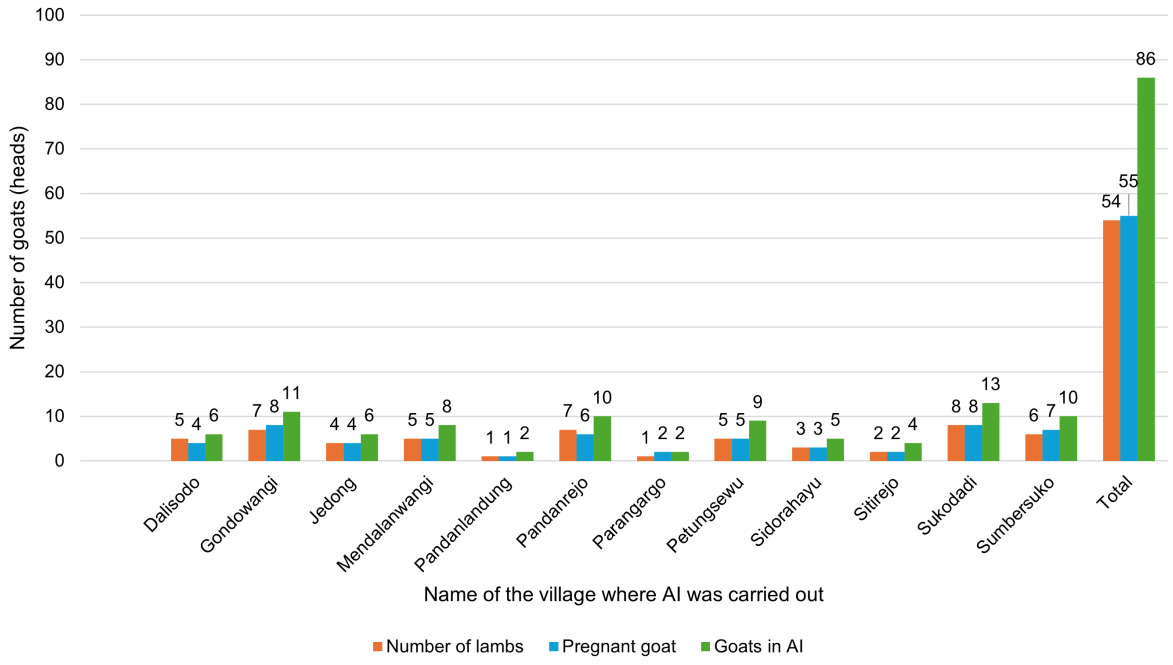

Figure 9 . The comparison of the number of lambs with pregnant and AI goats

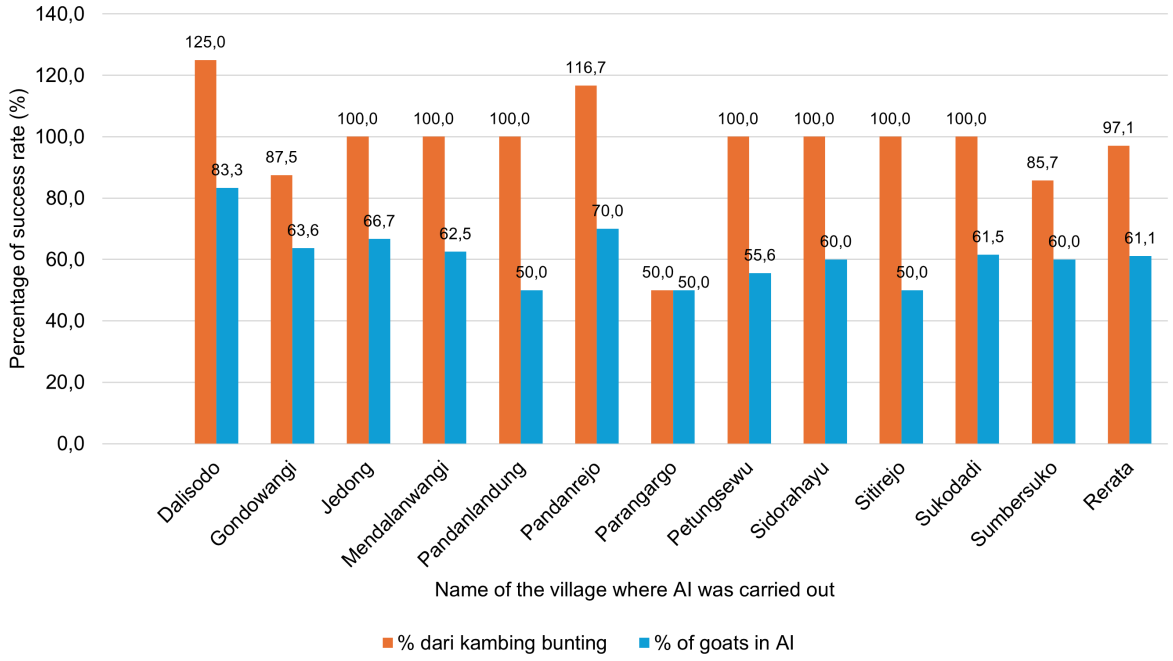

Figure 10 . The percentage of success rate of AI viewed from the number of pregnancies and the number of children born normally

the farmer's expectations (83%). The success of artificial insemination is very much determined by farm management, one of which is feed (Kusumawati, Ikhwan, et al., 2024) and maintenance which of course has an impact on livestock productivity (Anggita, 2023; Lusi et al., 2023).

Previous research findings (Alemayehu et al., 2021) showed that 142 (58.68%) goats and 53 (17.73%) sheep aborted. The average annual abortion percentage was 16.1% (±26.23) for goat ewes and 12.6% (±23.5) for sheep ewes. Farmers identified infectious diseases, extreme weather conditions, feed shortages, physical trauma, and plant poisoning as the primary causes of abortion in livestock. A higher incidence of abortion was observed during the short rainy season (March to May) and the early short dry and cold season (June to August), particularly in lowland and pastoral agroecological zones and mixed livestock production systems. Overall, 65.41% of sheep and 92.22% of goats tested positive for one or more abortion-causing agents, namely C. burnetti, C. abortus, Brucella spp., and T. gondii; mixed infections were found in 31.58% of sheep and 63.33% of goats. Sheltering in traditional pens and providing supplementary feed for pregnant ewes were important management factors that significantly ($p \leq 0.05$) reduced the risk of abortion by 2.63 and 4.55 times, respectively. However, the presence of other livestock species and dogs in the house and exposure of livestock to Brucella spp. or any of the four infectious agents tested significantly ($p \leq 0.05$) increased the risk of abortion in sheep and goats. In general, abortion is a challenge for small ruminant production in the study area especially in lowland agroecology and requires improvements in livestock practices, health care and biosecurity practices.

Based on the results of the pre-test and post-test, the targeted farmers knowledge achievements increased significantly from 20% to 90%. Moreover, the participants in the AI technology training using nanomaterial-assisted sexing semen were very enthusiastic in following the activities from beginning to finishing steps. The results of artificial insemination showed that the success rate of the AI was more than 60%. In goats and sheep, the success rate of more than 60% is considered good (Murtaza et al., 2020; Nuraini et al., 2021; Prihatin et al., 2021; Prihatin & Amam, 2022). The high success rate of AI technology with nanomaterial-assisted semen sexing is also due to the nanomaterial ampoules being able to maintain the quality of semen sexing (Kusumawati, Karyasa, et al., 2024) and inseminator skills (Kusumawati, Ikhwan, et al., 2024) as well as the knowledge of breeders in the field of reproduction, especially the recognition of estruses which determines the accuracy of identifying the time of estruses (Huza et al., 2023). The last stage is the field mentoring and monitoring activities which are also routinely carried out by the service team. The results of the activities showed a significant increase in awareness, knowledge, and skills in using AI technology with nanomaterial-assisted semen sexing. This also has an impact on increasing the productivity of goats and sheep.

The impact of the community empowerment activities was measured using a survey method conducted before and after the activities. The indicators included: (a) the level of participation of target partners, (b) the level of partner satisfaction with the implementation of community service activities, (c) the commitment, knowledge, and skills of partners in effectively implementing AI technology with nanomaterial-assisted semen sexing, and (d) the level of empowerment of the target community (members of

Table 1 . The impacts of community empowerment activities implementing AI technology with nanomaterial-assisted semen sexing

	Indicator	Before The Activity	After Activities
1	Level of participation of target audience partners	Fair (level 2 of 7 levels participation)	High (level 6 of 7 levels)
2	Partner satisfaction level	Not measured	High (level 4 of 5 levels)
3	Commitment, knowledge, and skills of partners in sustainably implementing AI technology with nanomaterial-assisted semen sexing	Low	Very high
4	Level of empowerment of the target community	Enough	High

PT KTHR and BUMDesMa Wagir Berkah) in the Wagir District area. Table 1 presents the conditions before and after the activities. Overall, the community service activities, from start to finish, were successful.

The outcomes of the activities indicate that the training, practice, and mentoring sessions were highly effective and received an overwhelmingly positive response from the community. These efforts had notable economic and social impacts, including a significant increase in farmers' income and a substantial improvement in skills related to AI technology with nanomaterial-assisted semen sexing, which rose from 20% to 90%.The increase in the productivity of goats and sheep owned also affects the income of farmers (Sujarwanta et al., 2024). In addition, of course, increasing the productivity of goats and sheep also provides benefits for regional development (Simões et al., 2021). Follow-up to community service activities is to provide assistance and post-activity monitoring as often as possible. Assistance is carried out once a week and monitoring once a month. This supports the market opportunities for goats and sheep which are very high and have the potential to be exported (Marius et al., 2020).

4. CONCLUSION

The community empowerment activities have been successfully implemented, thanks to the support and cooperation of all partners and farmers in Wagir District. These well-executed initiatives have led to a significant improvement in the awareness, knowledge, and skills of sheep and goat farmers in applying AI technology with nanomaterial-assisted semen sexing. These outcomes have had a meaningful impact by increasing the participation levels of the target farmer community members, as well as engaging stakeholders and collaborators. To sustain these benefits, regular and continuous mentoring and monitoring activities with partners are essential.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interest.

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