Original Article

Development of business models for indigenous genetic improvement in small ruminant farms through reproductive biotechnology

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Abstract

This study aimed to establish a business model of reproductive biotechnology in small ruminant. Sets of questionnaires were administered to interview 115 farmers from different regions in Thailand. Data including age, educational background, farm size and type, source of replacement breeders, breeding technology, farm problems and attitude toward the technology were collected. Logistic regression analysis along with neutral network analysis was used to identify factors associated technology interest with $P < 0.05$. Results showed that among 115 participants, 72.2% were interested in reproductive biotechnology. In univariate logistic regression analysis, farmer's age [OR=0.96, 95% CI (0.93,1.00)], educational background [OR=1.17, 95% CI (0.13,0.80)], production problems [OR=1.28, 95% CI (1.12,1.478)] and marketing problems [OR=1.40, 95% CI (1.18,1.67)] were independently associated with technology interest ($P < 0.05$). Similar to the neural network analysis, farmer's age, overall farm problems, marketing problems, production problems and educational background were the primary factors influencing technology interest of farmers. Next, the data from 18 semi-structured interviews were interpreted to establish suggested business models of reproductive biotechnology package. This indicated that a single business model could not fit the expectation of all farmers. Thus, six business models were established and 2 models were initially implemented in 7 farms with a moderate successful rate. In conclusion, the implement of reproductive biotechnology in small ruminant farm should be addressed to the young farmers with high education to improve the animal genetic value and sustain their livelihoods. However, the different farm managements play a key role in the success of these business models.

Keywords: business model, reproductive biotechnology, small ruminant farm

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Introduction

It has been generally accepted that small ruminant sector plays an important role in economic development of rural households world-widely. In Thailand, the national statistic by the Department of Livestock Development (DLD) reported that about half million of goat and sheep are raised by five hundred thousand families with an average of twelve animals per farm (DLD, 2015). However, these small holder farms frequently encounter the major problems including inbreeding, lack of breeders and lack of disease monitoring in the herd. Utilization of the reproductive biotechnology such as laparoscopic artificial insemination (LAI) and embryo transfer (ET) can help to solve these problems. These tools promote rapid genetic improvement, minimization of inbreeding and prevention of disease transfer among herds (Leboeuf *et al.*, 1998; Panyaboriban, 2015). The success rate of LAI reportedly ranges from 60% to 80% (Sathe, 2018). Generally, ET provides a pregnant rate about 37% to 80% (Bergstein-Galan *et al.*, 2018). However, the LAI and ET by Thai government services are limited encountering approximately only <1% of goat population. We hypothesized that a cooperation in a form of "Public-Private-Partnerships: PPPs" by a joint venture between university and private sector could be a suitable business model to implement the existing biotechnology to help small ruminant farmers. The objective of the present study was to establish suitable business models for the use of reproductive biotechnologies in small ruminants in small holder farmers. This was performed by studying the factors affecting the farmers' perception to the technology using questionnaire, semi-structured interview and also testing the efficiency in field practice.

Materials and Methods

This study conformed to the ethical standards issued by the National Research Council and was approved by Ethic Committee for Human and/or Animal Experimentation No. 1531062, the Faculty of Veterinary Science, Chulalongkorn University.

Study area: The study was conducted in 5 regions of Thailand based on sheep and goat production area, i.e. the central region (Bangkok (13°45'0'' N, 100°31'1.20''E) and Lopburi (14° 48' 0'' N, 100° 37' 12'' E) province), the western region (Ratchaburi (13° 32' 24'' N, 99° 49' 12'' E) and Kanchanaburi (14° 0' 15'' N, 99° 32' 57'' E) province), the eastern region (Chachoengsao (13° 41' 24'' N, 101° 4' 12'' E) province), the north-eastern region (Saraburi (14° 31' 48'' N, 100° 52' 48'' E), Nakhon Ratchasima (14° 58' 12'' N, 102° 6' 0'' E), Roi-Et (16° 3' 0'' N, 103° 39' 0'' E), Khon Kaen (16° 25' 12'' N, 102° 49' 48'' E), and Udon Thani (17° 24' 36'' N, 102° 47' 24'' E) province) and the southern region (Krabi (8° 11' 53'' N, 99° 0' 31'' E) province) (DGA, 2018).

Questionnaire: The goal of the questionnaire was to explore the relationships among factors that influenced farmers' interest in biotechnology. Various factors related to the technology utilization included farmer's age, educational background, farm size and type, source of replacement breeders, breeding technology and problems in the farm as shown in Table 1. The participants (n=115 farmers) were located from the central (n=25), north-eastern (n=44) and southern (n=46) parts of Thailand. All questionnaires were recorded and analysed for the relationships between relevant factors and the technology interest.

Table 1 Details of each factor that used in the study of the relationships with technology interests (n=115).

Factors	Details
Basic information	
Farmer's age (2 groups)	1. Age ≤ 46 years 2. Age > 46 years
Education background (2 levels)	1. Basic education 2. Certificate/ Higher degree
Animal Husbandry	
Farm size (3 sizes)	1. Small farm (<40) 2. Medium farm (40-80) 3. Large farm (>80)
Farming type (4 types)	1. Breeder farm 2. Meat farm 3. Dairy farm 4. Multi-purpose farm
Source of replacement breeder (3 sources)	1. Imported 2. Local farm 3. Multiple sources
Breeding technology (3 methods)	1. Natural insemination 2. Artificial insemination 3. Both methods
Overall farm problems (18 list of problems)*	1. Production problems (11 issues): A 2. Marketing problems (7 issues): B

***A) Production problems**: 1) expensive breed, 2) sparsity of purebred, 3) lack of high genetic breeder, 4) low conception rate, 5) lack of breeding management knowledge, 6) lack of government support, 7) lack of feed stock, 8) abortion/disease outbreaks, 9) unadapt to condition, 10) low growth rate and 11) inbreeding; **B) Marketing problems**: 1) unstable price, 2) state regulation of importation, 3) market uncertainty, 4) lack of processing, 5) specific consumer groups, 6) lack of advertising and 7) lack of animal sources.

Semi-structured interview: The data was collected from 18 farms from central (n=4), east (n=1), west (n=3), north-eastern (n=8) and south (n=2). The data included the number and source of animals, breed, feeding, insemination technique, insemination costs, reproductive performance on the farm, interest in reproductive biotechnology and factors or problems influencing sheep and goat production. Qualitative data analysis including preparing and organizing the data, coding, and presentation the data in the form of text (Creswell, 2007) were used to establish suggested business models on reproductive biotechnology.

On-farm technology testing: Seven from eighteen semi-structured interviews at central (n=1), eastern (n=1), north eastern (n=5) were selected to test our business models. Farm inclusion criteria included raising healthy animals, being a brucellosis-free herd, having good animal management practices (husbandry and reproduction), and compliance with data recording. The procedures for implementation were started with gathering herd status, pregnancy diagnosis. Then, suitable biotechnology, e.g. synchronization program, cervical artificial insemination (CAI), LAI, ET, and semen cryopreservation were chosen to perform according to the customer needs and farm performance. After checking for the conformity, the results of on-site testing were monitored regularly in order to follow up the implementation.

Statistical analysis: The statistical analyses were carried out using IBM SPSS Statistic Version 22.0 (SPSS; IBM, Armonk, NY, USA). The data from the questionnaires and interviews were displayed as descriptive statistics. The relationships among socio-economic factors (farmer's age, educational background, farm size, farm type, source of replacement breeders, breeding technology, and level of problems at the farm) and attitudes toward receptivity of reproductive biotechnology were explored using two methods, i.e. univariate logistic regression; $P < 0.05$ was set as level of significance and neural network analysis.

Results

A total of 72.2% of 115 respondents were interested in reproductive biotechnology. In line with our expectations, significant relationships were found between farmers' technology interest and several socio-economic factors using univariate logistic regression analysis (Table 2). The farmer age (Fig. 1a) was significant related with the farms' interest in obtaining the technology where older farmers (>46 years) were less technology interest [OR=0.96, 95% CI (0.93,1.00)]. The farmers' educational background (Fig. 1b) also significant affected the farmer attitudes which the farmers with a certificate/ higher degree were more technology interest [OR=1.17, 95% CI (0.13,0.80)].

From the present study, there were no significant relationships between technology interest and farm size, farm type, source of animal replacement and breeding method. Whilst the larger proportion of the farmers that were interested in technology are small holder farms (Fig. 1c), producing meat farm type (Fig. 1d), purchasing replacement breeders from local farms (Fig. 1e) and using natural insemination (NI) (Fig. 1f).

Interestingly, we found that overall problems in farm [OR=1.19, 95% CI (1.09,1.30)] including the total score of production problems [OR=1.28, 95% CI (1.12,1.478)] and the total score of marketing problems [OR=1.40, 95% CI (1.18,1.67)] were significant associated with farmers' technology interest as shown in Table 3 and Fig. 1g. Indeed, specific problems in farm that tend to influencing the technology interest of farmers were lack of high genetic breeder [OR=3.14, 95% CI (0.93,10.63), P = 0.07], lack of government support [OR=2.98, 95% CI (0.97,9.16), P = 0.06] and low growth rate [OR=0.30, 95% CI (0.07,1.20), P = 0.09].

Table 2 The univariate logistic regression analysis of socio-economic factors influencing farmers' technology interest (n=115)

Factor	Farmer number	OR	*P*-value	95% confidence interval Lower-Upper
Basic information				
Age (year)				
1. ≤46	56	Ref.	-	-
2. >46	59	0.96	0.03	0.93-1.00
Education				
1. Basic education	64	Ref.	-	-
2. Certificate/ Higher degree	51	1.17	0.01	0.13-0.80
Animal Husbandry				
Farm size				
1. Small farm (<40)	69	Ref.	0.49	-
2. Medium farm (40-80)	33	0.76	0.55	0.31-1.86
3. Large farm (>80)	13	2.10	0.37	0.42-10.32
Farm type				
1. Breeder farm	5	Ref.	0.80	-
2. Meat farm	82	1.61	0.61	0.25-10.26
3. Dairy farm	5	2.67	0.50	0.16-45.14
4. Multi-purpose farm	23	2.40	0.40	0.31-18.55
Source of replacement breeder				
1. Imported	1	Ref.	1.00	-
2. Local farm	112	$4.22*10^8$	1.00	0.00
3. Multiple sources	2	0.00	1.00	0.00
Breeding technology				
1. Natural insemination	98	Ref.	0.68	-
2. Artificial insemination	1	0.55	0.38	0.15-2.07
3. Both methods	16	$3.72*10^8$	1.00	0.00

Table 3 The univariate logistic regression analysis of factors related to farm problems that influencing farmers' technology interest (n=115)

Factor	Farmer number	OR	*P*-value	95% confidence interval Lower-Upper
Overall farm problems	115	1.19	<0.01	1.09-1.30
Production problems				
1. Expensive breed	88	1.59	0.47	0.46-5.54
2. Sparsity of purebred	92	2.45	0.24	0.56-10.75
3. Lack of high genetic breeder	75	3.14	0.07	0.93-10.63
4. Low conception rate	47	0.46	0.26	0.12-1.79
5. Lack of breeding management knowledge	84	0.78	0.74	0.18-3.36
6. Lack of government support	71	2.98	0.06	0.97-9.16
7. Lack of feed stock	59	1.89	0.28	0.59-6.03
8. Abortion/Disease outbreak	67	2.80	0.12	0.76-10.38
9. Unadapt to condition	65	0.97	0.96	0.29-3.23
10. Low growth rate	73	0.30	0.09	0.07-1.20
11. Inbreeding	62	1.46	0.56	0.41-5.15
12. Total score	115	1.28	0.00	1.12-1.47
Marketing problems				
1. Unstable price	82	1.43	0.61	0.37-5.60
2. State regulation of importation	76	1.18	0.79	0.34-4.16
3. Market uncertainty	83	0.83	0.79	0.20-3.44
4. Lack of processing	94	0.28	0.17	0.05-1.69
5. Specific consumer groups	86	0.77	0.71	0.20-2.95
6. Lack of advertising	83	1.05	0.95	0.26-4.17
7. Lack of animal sources	66	0.27	0.21	0.09-0.82
8. Total score	115	1.40	0.00	1.18-1.67

In addition, to explore the relationship between farmers' technology interest and various factors, the neural network analysis (a deep learning process in IBM SPSS 22) was carried out with the set of data training at 75% and testing at 25%. On the basis of the normalized importance, farmer's age (100%) was found to be the most important factor influencing farmers' technology interest followed by overall farm problems (66.1%), marketing problems (55.5%), production problems (51%) and farmers' educational background (42.2 %), respectively (Fig. 2).

Based on data from 18 semi-structured interviews, it can be concluded into six different business models on reproductive biotechnology (Fig. 3) that resolve specific farmer needs as follows: 1. Providing artificial insemination (AI) using fresh semen from breeders in farm or imported frozen semen, 2. Providing fresh or frozen embryos transfer to the recipients within farm, 3. Selling pregnant females that inseminated using AI technique, 4. Selling pregnant females using embryo transfer technique, 5. Selling offspring born by AI or ET technique and 6. Servicing provision of reproductive biotechnology.

Lastly, seven potential goat farms were selected to perform on-farm technology testing. The two business models (1 and 6) were initially implemented accordingly to the farmer's wish and their farm potential. The pregnancy diagnosis (regarding the business model 6) was carried out toward all farms whereas six farms preferred to further our service using LAI (regarding the business model 1) with the successful results varied from 14.3 to 57.1%. Only one farm that preferred using cervical AI showed pregnancy rate at 33.3% (Table 4).

Discussion

The present study explored the relationships between farmers' technology interest and underlying factors including socio-economic status and problems found in farm by direct interviewing of 115 small ruminant farm owners. Then, the empirical analysis of 18 semi-structured interviews has revealed six distinctive types of business models on reproductive biotechnology in small ruminant farm which has never been reported to the best of the authors' knowledge; in this case, technology acceptance must be made through the establishment of business model and actual on-farm testing. These developed business models can help to solve the common pain points of small ruminant farm production, e.g. inbreeding, lack of good genetic breeders and these models also aimed at preventing the introduction of disease into herd.

The modern analysis using neural network harmonized with the data from regression analysis in this study revealed the top 5 primary factors affecting farmers' technological interests, i.e. farmer's age, farmers' education background, overall farm problems, marketing problems and farm production problems. This indicates that farmer's socio-economic characteristics play a very important role in technology interest. Indeed, the age of the farmer has a negative impact on technology interest. Therefore, the young farmers with a higher educational background were the prospective customers who interested in using the technology to improve the herd genetics. Although the farm size did not significantly influenced farmers' technology interest, but using biotechnology in farm to enhance the productivity may suitable for small farm size because they lack of good breeders. In general, the goat farms in Thailand for meat production are operated with various mixed breeds, local and crossbred etc. while dairy farms present only less than 5% of total goat population (DLD, 2018). Since most of small ruminant farm in Thailand are indigenous, crossbred and exotic breeds (Anothaisinthawee *et al.*, 2010) with a lack of systemic breeding improvement. Typically, it is well known that native species were growing slower than the imported species (Doloksaribu *et al.*, 2000). Therefore, the use of technology to assist in breeding program was directly useful for farmers. Hence LAI and ET can serve to improve the local and crossbred genetic for meat and milk production. Owners of farms that use natural insemination were highly interested in technology because they needed to breed with semen of high quality and high genetic instead of natural mating. However, the AI services by Department of Livestock Development is currently less than 1% coverage (DLD, 2017). Therefore AI service in small ruminant industry is still in high demand. This is another clue to indicate that farmers have needs to receive technology but services from the public sector may not be sufficient for meeting farmers' needs.

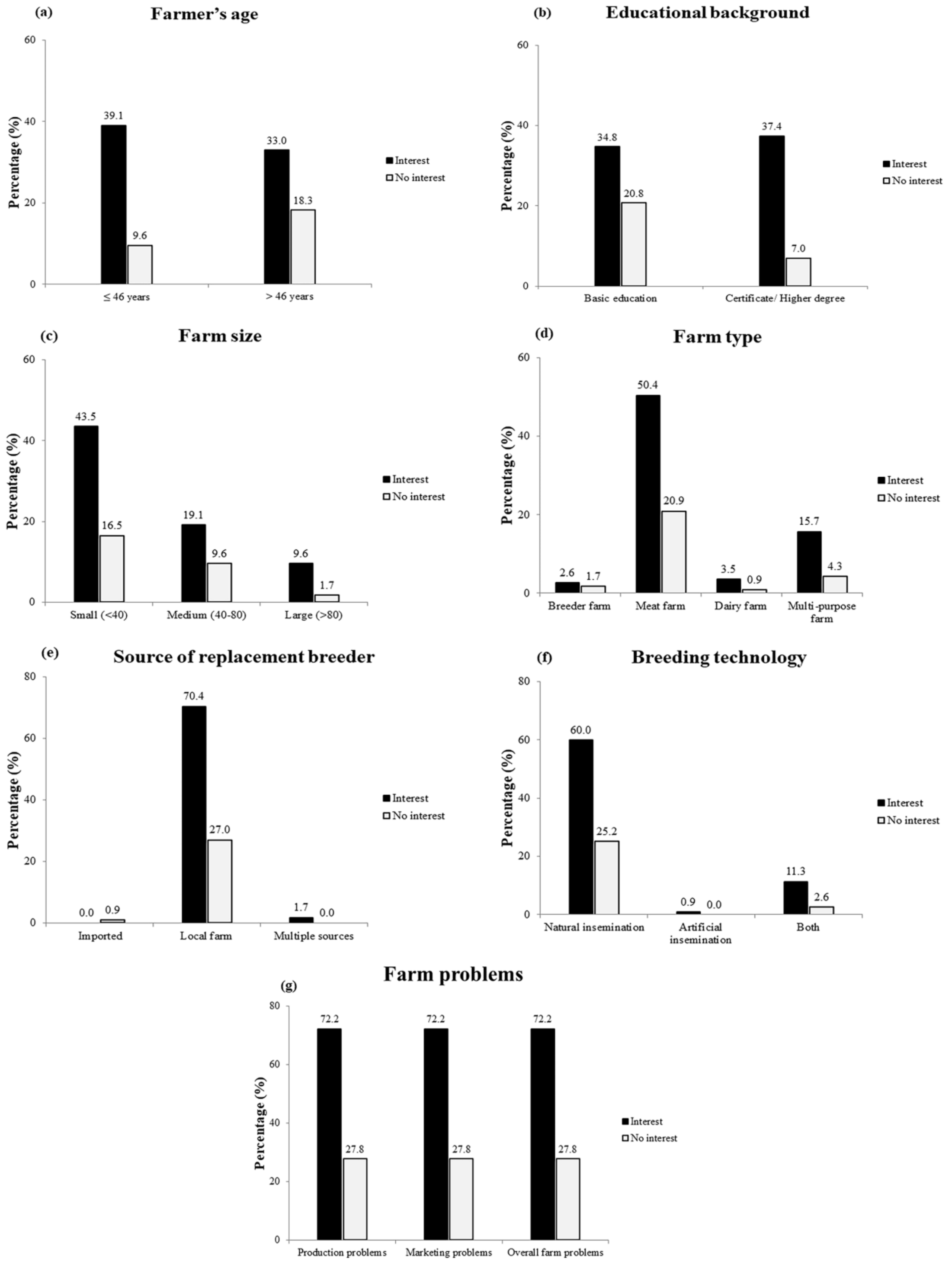

Figure 1 The factors affecting on farmers' technological interests including a) farmer's age, b) educational background, c) farm size, d) farm type, e) source of replacement breeder, f) breeding technology, g) farm problems.

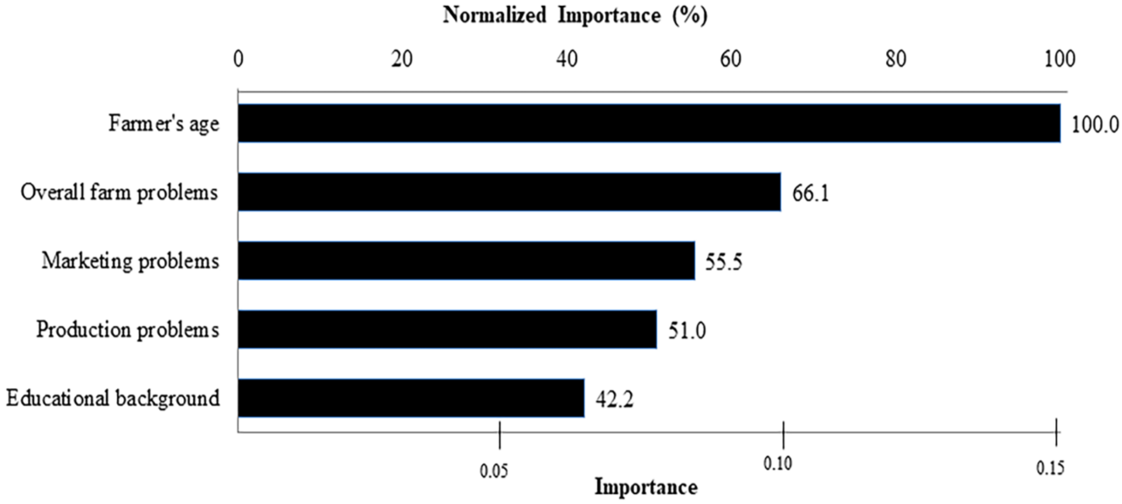

Figure 2 The top 5 primary factors affecting farmers' technology interest using the neural network analysis.

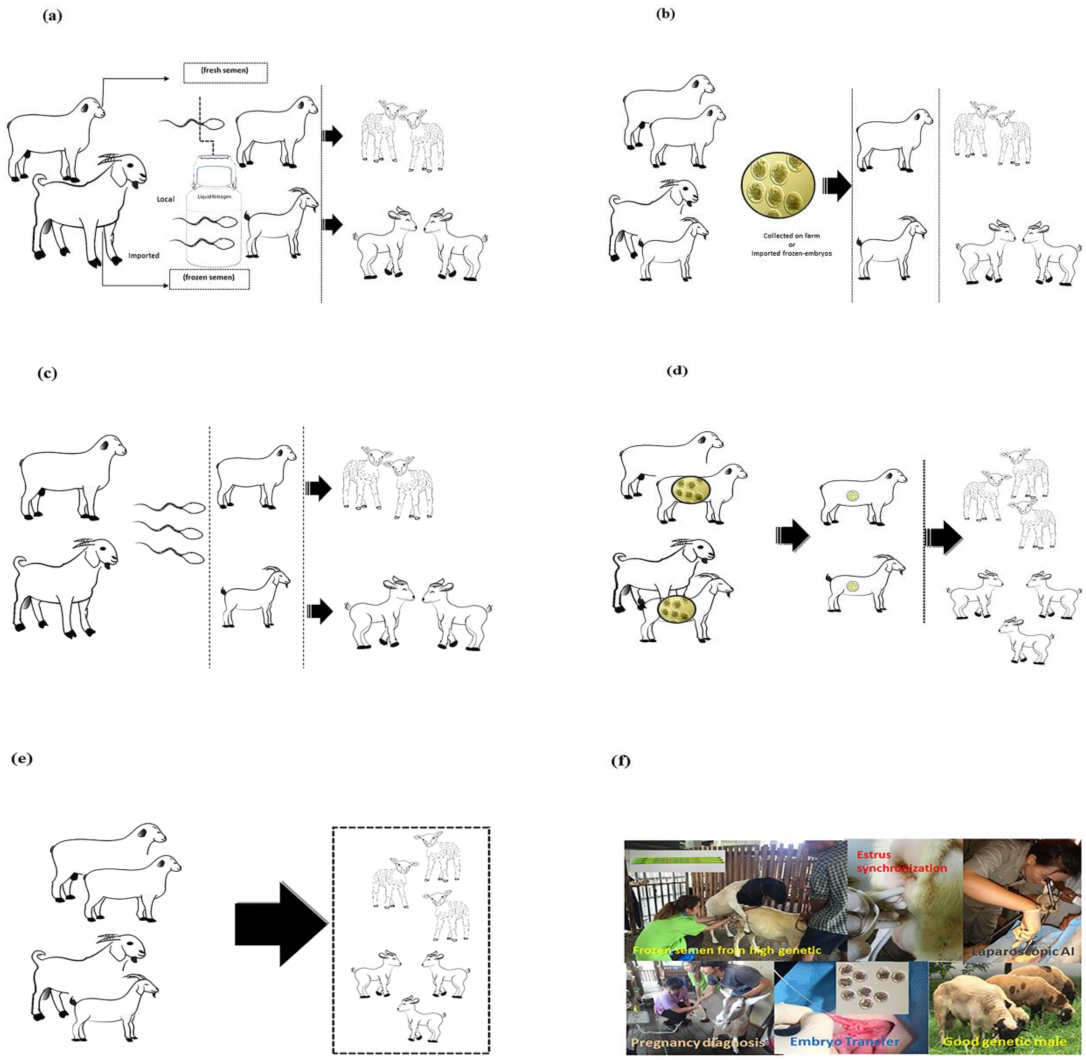

Figure 3 The business model from 18 semi-structured interviews that used to implement in sheep and goat farms. a) Model 1: Providing AI using fresh semen from breeders in farm or imported frozen semen, b) Model 2: Providing fresh or frozen embryos transfer to the recipients within farm, c) Model 3: Selling pregnant females that inseminated using AI technique, d) Model 4: Selling pregnant females using embryo transfer technique, e) Model 5: Selling offspring born by AI or ET technique and f) Model 6: Servicing provision of reproductive biotechnology such as semen collection and freezing, estrus synchronization.

Table 4 On-farm testing (farms that received technology services) (n=7)

Farm	Province	Services				
		Pregnancy diagnosis	LAI	Pregnancy rate (%) of LAI	CAI	Pregnancy rate (%) of CAI
1	Bangkok	120	21	12 (57.1%)	3	1/3 (33.3%)
2	Chachoengsao	25	ND	ND	ND	ND
3	Roi-Et_1	34	8	4 (50%)	ND	ND
4	Roi-Et_2	20	7	1 (14.3%)	ND	ND
5	Roi-Et_3	25	12	6 (50%)	ND	ND
6	Roi-Et_4	27	17	7 (41.2%)	ND	ND
7	Udon Thani	29	27	4 (14.8%)	ND	ND
	Total	282	92	34 (36.9%)	3	33.3%

ND, not done

Our study also showed that farmers who faced the problems in farm were likely to pay attention to adopt technology in their farm in order to solve their specific problems such as lack of high genetic breeder, lack of government support and low growth rate [OR=0.30, 95% CI (0.07,1.20), *P* = 0.09]. Based on this information, the problems that affect farmers' breeding also involve both production efficiency and marketing. Thus, if technology can actually tackle breeding problems, the production and marketing problem should be solved and farmers will therefore pay more attention to the advanced biotechnology.

The current study also revealed that networking plays a important role in promoting participation of different sectors in the small ruminant industry. A cooperation in form of Public-Private-Partnerships by a joint venture between university and private sector is the key process to implement the business models that covered the use of reproductive biotechnology in small/large ruminant farms. The value of AI services can be offered in Model 1 (providing AI using fresh semen from breeders in farm or imported frozen semen) and Model 3 (selling pregnant females that inseminated using AI technique). The high genetic offspring can be provided in pregnancy ewes by selling an offspring as in Model 3 and 4 (selling pregnant females using embryo transfer technique). If the farmers need the purebred, they can choose Model 2 (providing fresh or frozen embryos transfer to the recipients within farm) or Model 4 by earning on-farm ET services which giving a 100% desired genetics. In addition, our findings indicated that some small-holder farmers did not participate in the on-farm biotechnology testing due to some barriers, i.e. poor herd health management, lack of reproductive management program and without budget constraints. The veterinary services in reproductive management such as pregnancy diagnosis, estrus synchronization will help to solve the problems such as pseudopregnancy and increase farm potential. Due to a high prize of pure breeder, costing around 1,500 US dollars per head, it is suitable to apply model 3, 4 and 5 (selling offspring born by AI or ET technique) to provide a good genetic of 50% crossbred breeders from AI or purebred from ET in form of pregnant animals or offspring. In addition, the offspring born from ET that offered in Model 5 can be purchased to small-holder farms that couldn't perform ET services in their farms.

As with any study, each business model developed in this study possesses different advantages and disadvantages. Model 1 is capable of increasing the rate of genetic improvement of local breeds in farm via AI technology at a relatively low cost while restricting the rate of inbreeding and reducing transmissible venereal diseases (Van- Arendonk, 2011). Using imported frozen semen may also reduce the cost of having male breeder in the farm and enable the farmer opportunity to select the desired characteristics for male breeder. However, the use of frozen semen results in lower conception rates compared to the fresh semen. Frozen-thawed semen showed significantly lower kidding rates (43.9%) than that with fresh semen (59.8%) (Apu *et al*., 2012). However, this model had attracted some attention from the farmers and had been serviced on-farm because the cost is not very high. Model 2 offers the use of fresh embryos derived from animals within the farm. Many lines of evidences showed that the survival rate of fresh embryos is higher than that of imported frozen embryos (Pavone *et al*., 2011; Vladimirov *et al*., 2017). On the other hand, imported frozen embryos have high genetic values that enable an increasing of genetic improvement without the need for having purebred rams in farm. This model carries some risks and price considerations. Our findings found that there were some farmers who are both ready and not ready to adopt this model in their farms. Model 3 offers farmers to purchase ewes already pregnant by AI technology. This approach reduces farmers' risk of investment because a successful conception is time-consuming process. However, the genetic values of offspring from those ewes were limited improvement under dependent of genetic from semen of rams. Model 4 help rapid increasing of breeding management with excellent genetics because the embryos in the pregnant recipient ewes were selected from the oocytes of high genetic value donor ewes which had been inseminated with semen of the top rams. This model is suitable for a small number of high-performing farms that followed good practices, so this technology is still limited in the narrow band for the breeding schemes for small ruminant populations in developing countries. Model 5 will allow animals (the offspring born from AI and ET) to adapt defensive system to their ambient environments (Vandenbergh *et al*., 2002; Wu and Bazer, 2019). It was indicated that most farmers pay attention with this model because it produces concrete results from reasonable investment. However, farmers must accept the risk of loss during taking care of the offspring and also it cannot be guaranteed that all purchased offspring will be able to showed normal reproductive function. Lastly, Model 6 (servicing provision of reproductive biotechnology) provides various choices of on-site reproductive biotechnology services such as CAI, LAI, embryo flushing, embryo cryopreservation, oestrus synchronization, and pregnancy diagnosis. This model can be applied in various circumstances because there are several techniques to use, so that the techniques are tailor-made for each farm.

Regarding on-farm implementation, we found that farmers were most accepted to perform pregnancy diagnosis using ultrasonography to screen the reproductive status of their herds because the ultrasound technology provide practical, non-invasive and accurate results. In addition, ultrasound technique offers another way to detect reproductive problems, e.g. pseudopregnancy. In our previous study showed that pseudopregnant ewes can be cured by progesterone implantation in combination with prostaglandin F2α (PGF2α) and became pregnant with a success rate of 40% (2/5) (Khunmanee *et al.*, 2017). In this context, the mean value of pregnancy rate following an implementation of biotechnology was lower than the previous study (Panyaboriban *et al.*, 2018). This result can be explained by many factors including animal fertility, different management program and difficulty to control farm conditions throughout the study period (Duran, 2018).

In conclusion, six business models for reproductive biotechnology package in small ruminant farms such as estrus synchronization, pregnancy diagnosis, LAI, ET and reproductive problem solving were established based on the information from questionnaire, semi-structured interview and on site technology testing. This tailor-made solution will help farmers to increase the production efficiency and thus improve their livelihoods. There are several factors affecting on the farmer's perception on technology such as age, educational background and farm problems that we need to concern. A reliable networking in small ruminant value chain and long-term commitment are needed in order to achieve a successful adoption of this technology.

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