

Knowledge, attitudes, and practices of smallholder farmers on foot and mouth disease control in two Cambodian provinces

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Abstract

Food-and-mouth disease (FMD) is endemic in Cambodia. The control program for FMD has relied on vaccination, with poor vaccination uptake by smallholder farmers an increasing concern. A study to improve the understanding of farmer knowledge, attitudes and practices of FMD and FMD vaccination was conducted in two Cambodian provinces. The aim was to identify opportunities to improve the disease control programs provided by both the government and private sectors. The survey comprised 300 smallholder farmers using a one-on-one interview technique. Results identified that over two-thirds of the respondent farmers had not vaccinated their cattle over two years. Of those who did, most cattle were vaccinated either once a year or once every three years. A booster had never been administered. FMD outbreaks occurred every year during the study period, with a morbidity rate of over 30%. Isolation of first infected cattle from the household herd was not practiced, with treatment identified as the first preference intervention. Farmers often assisted other farmers to restrain and treat infected cattle both before (57%) and after (43%) their own cattle were infected. This indicated that most farmers did not practice basic biosecurity measures and chose to report FMD outbreaks to the village animal health workers (VAHW), friends, neighbors, and relatives in preference to government officials. It was concluded that poor knowledge of disease transmission and biosecurity, with low FMD vaccination coverage and a focus on treatment, contribute to regular FMD outbreaks in these communities. Improvement of FMD control requires the cooperation of villagers, VAHWs, and village leaders in disease reporting, with either improved funding of government vaccination services or private FMD vaccination service. Training programs for farmers on disease transmission, and the importance of biosecurity and vaccination, including information on the cost-benefits of treatment versus full fee bi-annual FMD vaccination, are required.

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Running head: Food and mouth disease control in Cambodia

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Summary

Food-and-mouth disease (FMD) is endemic in Cambodia. The control program for FMD has relied on vaccination, with poor vaccination uptake by smallholder farmers an increasing concern. A study to improve understanding of farmer knowledge, attitudes and practices of FMD and FMD vaccination was conducted in two Cambodian provinces (Kampong Cham and Pursat). The aim was to identify opportunities to improve the disease control programs provided by both the government and private sectors. The survey comprised 300 smallholder farmers using a one-on-one interview technique. Results identified that over two-thirds of the respondent farmers had not vaccinated their cattle over two-year period. Of those who did, most cattle were vaccinated either once a year or once every three years. A booster had never been administered. It was concluded that the FMD vaccine had only been administered through an unreliable and limited government vaccination program, and private FMD vaccination services were not accessed in the study areas. FMD outbreaks occurred every year during the study period, with a morbidity rate of over 30%. Isolation of first infected cattle from the household herd was not practiced, with treatment identified as the first preference intervention. Farmers often assisted other farmers to restrain and treat infected cattle both before (57%), and after (43%) their own cattle were infected. This indicated that the majority of farmers did not practice basic biosecurity measures and chose to report FMD outbreaks to the village animal health workers (VAHW), friends, neighbors and relatives in preference to government officials. It was concluded that poor knowledge of disease transmission and biosecurity, with low FMD vaccination coverage and a focus on treatment, contribute to regular FMD outbreaks in these communities. Improvement of FMD control requires the cooperation of villagers, VAHWs and village leaders in disease reporting, with either improved funding of government vaccination services or establishment of a private FMD vaccination service. Training programs for farmers on disease transmission, and the importance of biosecurity and vaccination, including information on the cost-benefits of treatment versus full fee bi-annual FMD vaccination, are required.

Key Words: Foot and mouth disease, Cambodia, cattle, smallholder farmer; vaccination

1. Introduction

Cambodia is a Southeast Asian country of 181,035 km² that shares borders with the Lao People's Democratic Republic (PDR) in the north, Thailand in the north and west, and Vietnam to the south and east. Cambodia is divided into 24 provinces and one municipality, with a population, estimated at 16.3 million (World Population Review, 2019). Agriculture is integral to the life of rural communities, with almost 90% of large ruminants owned by smallholder farmers (Pen, Savage, Stür, & Seng, 2009). The majority of smallholder farmers use traditional husbandry systems to raise their livestock, with cattle vital to rural smallholder farmer households. Most cattle are typically fed native grasses and rice straw, usually in a cut-and-carry system involving most of the household members, including women and children. This system is labor intensive, particularly when feed availability is low, as in the dry season, and where the majority of the land is under rice and other crop cultivation in the wet season.

For smallholder farmer households, cattle are both a source of income and an economic asset and are frequently managed together with other agriculture farming activities, including rice, production of other crops, small livestock raising and other off-farm activities (Samkol, Sath, Patel, Windsor, & Holtenius, 2015; Young et al., 2014b). Smallholder farmer cattle management systems are typically basic, and most smallholder farmers have a poor understanding of disease risks and basic biosecurity (Nampanya, Suon, Rast, & Windsor, 2012). Limitations to cattle production in Cambodia and Lao PDR have previously been attributed to poor animal feeding practices, poor reproductive performance, and poor herd health management and biosecurity practices by the farmer (Nampanya et al., 2012; Stur, Gray, & Bastin, 2002; Windsor, 2011; Windsor, Suon, & Khounsey, 2008).

Animal disease outbreaks pose significant threats to livestock sectors throughout the world, both from the economic impacts of the disease and the costs of mitigating the disease risk. In the developing world, livestock diseases have broad effects on markets, poverty, and livelihoods (Rich & Perry, 2011). Amongst animal diseases, foot and mouth disease (FMD) has perhaps received the most attention due to concerns that significant budgets are required to reduce the risks of global disease transmission. In the Greater Mekong Subregion (GMS), control of FMD has been particularly problematic (Blacksell, Siengsan-Lamont, Kamolsiripichaiporn, Gleeson, & Windsor, 2019). FMD is endemic in the GMS and recognized as the most significant transboundary animal disease (TAD) affecting large ruminants, causing significant financial impacts at smallholder farmer household (Young et al., 2013) and the national level (Young, Nampanya, Khounsey, Bush, & Windsor, 2014a). The GMS is within FMD virus Pool 1, with recent epidemics involving isolates of O (Cathay, SEAMya-98, Pan Asia), A (SEA 97) and less commonly Asia 1 serotypes that have spread through much of South-East and eastern Asia, including Laos, Cambodia, Myanmar, Thailand, Vietnam, Malaysia, China, Korea and Japan (Blacksell et al., 2019; Perry, Gleeson, Khounsey, Bounma, & Blacksell, 2002). Several studies in Cambodia and Lao PDR have indicated that the impact of FMD on smallholder farmers is high due to the reduction of cattle value at the household and village levels (Nampanya et al., 2015; Young, Suon, Andrews, Henry, & Windsor, 2012).

Many countries in the world have adopted various approaches and measures to control the spread of FMD, including vaccination, movement restrictions and biosecurity, improved surveillance, public awareness programs, and in some jurisdictions, destruction of infected animals (Keeling, Woolhouse, May, Davies, & Grenfell, 2002). Where FMD is endemic, six-monthly vaccination and restriction of the movement of infected animals and their products are considered critical interventions (Parida, 2009). FMD control in Cambodia has relied mainly on ring vaccination surrounding outbreaks, although the actual interventions depend on the local circumstances, including the availability of funds and the cost of FMD vaccines. Achieving adequate vaccination coverage to produce effective herd immunity, both nationally and within villages is a major challenge in Cambodia (Sieng & Kerr, 2013) with vaccination coverage of the national large ruminant population estimated at 2% in 2010 (Young et al., 2013). However, farmers generally have a poor understanding of the need for FMD vaccination and have financial constraints that limit investments in disease risk management (Ashley et al., 2018; Young et al., 2017).

With data lacking on the current participation of smallholder farmers in FMD control programs in Cambodia, this study was designed to collect information regarding the knowledge, attitudes, and practices of 300 smallholder farmers toward FMD vaccination programs and investigated several potential key factors associated with implementing FMD control programs in the study areas. This information is considered important in providing an improved understanding of the relevance of different disease control practices, potentially providing strategies to encourage smallholder farmers to consider investing in preventive disease programs involving FMD vaccination in their communities.

2. Materials and methods

2.1 Target sites and survey population

The provinces of Kampong Cham (KC) and Pursat (PS) were purposively selected for this study. These provinces contribute significantly to cattle production and contain primary access routes for the cattle trade

into Vietnam. PS is located in the west of the country, bordering four provinces, the Tonle Sap (Sap River, a tributary of the Mekong River) and Thailand, whereas KC is located in the central lowlands of the Mekong River, bordering six provinces, the Mekong River and Vietnam. Target smallholder farmer households for the study were households participating in the ‘Domestic and International market development for high-value-cattle and beef in South-East Cambodia’ project (ACIAR project AH/2012/046), a collaborative research effort facilitated by the University of New England and the Cambodian General Department of Animal Health and Production (DAHP), with funding by the Australian Centre for International Agricultural Research (ACIAR). The communes and villages targeted for the survey were identified and selected through discussions and consultations between the researcher, representatives of the Provincial Office of Animal Health and Production (POAHP), and the ACIAR-funded project team located in DAHP and POAHP offices. These communes and villages were considered more likely to have an outbreak of FMD than other areas, and village selection was based on the main criteria of “at least 50% of households kept cattle”. Subsequently, five villages were selected in each of the two provinces. A total of 300 smallholder farmers with at least three cattle per household were identified for the survey, comprising 150 in each province.

2.2 Survey questionnaire design and interview technique

A semi-structured questionnaire consisting of open, closed and semi-closed questions was developed to collect both quantitative and qualitative information from the smallholder farmers. The questionnaire was developed in English and translated into Khmer, ensuring all questions were easy to understand and answer. The questionnaires collected information on the background of farmers, household assets, household incomes, cattle management, cattle trading, knowledge and experiences of diseases and vaccination practice, and the financial impact of FMD and perception on the importance of vaccination. In addition to the specific questions, information on opportunities and obstacles in the previous FMD vaccination programs was elicited, and suggestions for improvements to future vaccination programs obtained. Before the survey, the independent survey team received a full day of training to ensure they understood the aims and objectives of the study and were confident in their roles. To ensure best practice, a pilot study was carried out to test the survey questions, delivery technique and the length of time required for the interview. After initial field testing, the survey questionnaires were reviewed and revised according to feedback by the team. To ensure confidentiality and encourage honest responses from the farmers, government officials were excluded from participation in the interviews. At the end of the session, completed questionnaires were checked to ensure that no information was missing.

2.3 Data collection and analysis

The survey data were collected, translated from Khmer into English and transcribed into a database. The statistical analysis was performed using SPSS version 21.0 (SPSS Inc., IL, USA). Outlier values were compared with the questionnaires and corrected where necessary. Standard descriptive analysis of the data was performed to summarize household and livestock information, cattle trading, household assets and incomes, knowledge, experiences of FMD and vaccination practice, plus their perceptions on the importance of vaccination. Statistical analyses were undertaken by the application of both univariable and binary logistic regression methods. The influence of smallholder farmer attitudes and knowledge on FMD outbreak and vaccination practices were classified into three groups: age, education, and the number of household members; livestock husbandry and management; and vaccination knowledge. Variables from each group were subsequently tested against the binary independent variable of whether farmers had undertaken vaccination (i.e., Yes or No to FMD vaccination) using the Pearson’s chi-square test for independence and a P values <0.05 as evidence of significance. Odds ratios (OR) and their 95% confidence interval were also calculated to measure the magnitude of the association between factors and yes/no of the dependent variable. Variables that were significant at $P \leq 0.25$ in the univariate analyses were selected for inclusion in a logistic regression model (Hosmer & Lemeshow, 2000). The model was performed using backwards conditional testing, and odds ratios were calculated. In the final model, variables with P values >0.05 and which had value 1 in the 95% confidence interval of OR were excluded. The model was evaluated by calculating the Hosmer and Lemeshow statistical methodology (Hosmer & Lemeshow, 2000).

3. Results

3.1 General household characteristics and assets

A total of 300 smallholder farmers participated in the survey, with the study villages, communes, districts and provinces displayed in (Table 1). Of these, the same proportion of male (50%) and female (50%) respondents participated in KC, although female participants were higher (60%) in PS.

>Insert Table 1<

The mean age of the smallholder farmers was 46 years in both provinces. Fifteen per cent of smallholder farmers had off-farm paid employment. Two-thirds of respondents in both provinces were identified as a primary decision-maker in the household, while the remainder discussed issues with their family members before making any decision. The education level was similar in both study provinces. Approximately a quarter of the smallholder farmers (24%) had no formal education, only 58% had completed primary school, with no farmer participants in either province having tertiary education. The general education of smallholder farmers was low compared to other household members. Compared to respondents, a much lower proportion of household members had no formal education (11%), and a higher proportion (56%) had post-primary education. The majority of smallholder farmers owned paddy fields (Table 2). The average area of paddy fields was 1.4ha in KC compared to 2.2ha in PS. Approximately one-quarter of smallholder farmers in both study provinces owned land for other crops (1.03 ha in KC and 1.57 ha in PS). Smallholder farmers in KC owned slightly more cattle (4.6) and pigs (3.7) on average than smallholder farmers in PS. However, smallholder farmers in PS owned more ducks (10.5) and chickens (14.1) on average than smallholder farmers in KC. Other household assets are displayed (Table 2).

>Insert Table 2<

Nearly half of the interviewed smallholder farmers in both study provinces had borrowed money in 2013. The majority of smallholder farmers not borrowing money (80%) stated that they had no need, with a small proportion mentioning they were either afraid they could not repay the debt (27%), high interest rates (4%), and there was an unwillingness of moneylenders to provide a loan (4%). Of the farmers borrowing money, 37% used the money for general purposes in the family, 30% used the money to buy agricultural equipment, with the remainder using money to either buy cattle, repay debt, pay for labor-hire, expand the household business, or buy land.

3.2 Annual household income in 2013

In general, the incomes of smallholder farmer households varied between the study areas. The total income of smallholder farmer households was sourced from 3 main categories: agricultural cropping (rice and other crops), off-farm employment (salary employment, paid labor, remittances, small shop) and sale of livestock. The income from off-farm activities was mainly obtained from migrant household members working abroad. Overall, the average annual total household income was USD1,711 per household (range USD 250-8,400) in KC and USD2,075 (USD 250-10,425) in PS. In KC, off-farm activities contributed 38% of the total household income, followed by income from sales of livestock (34%) and on-farm activities (28%). On-farm activities contributed more to total household income (43%) in PS, followed by sales of livestock (29%) and off-farm activities (28%). Overall, animal raising contributed nearly one-third of the annual total household income of smallholder farmers in the study areas.

3.3 Cattle management and trading

Nearly two-thirds of the smallholder farmers were full-time farmers directly involved in rice farming and livestock keeping, while 32% and 41% were only engaged part-time in KC and PS, respectively. A small proportion was not actively engaged in family farm activities, although their family members did work with livestock and other farm activities. Half of the smallholder farmers (52%) in both study provinces acknowledged that women is directly involved in the livestock keeping activities. Smallholder farmers used different methods to house their cattle. During the night, most farmers in both study areas (62%) tethered

cattle under their houses, and others kept them together in pen near the house (35%), or a fenced paddy field (14%). A few farmers admitted that they kept cattle along the road (5%). During the day, a fenced paddy field near the house was a common area to keep cattle reported by the majority of smallholder farmers (81%). Many farmers housed their cattle in pen (34%) and some kept the along the roadsides (25%). Grazing on available pastures in the fields was a common way of feeding cattle but varied with the seasonal. In the rainy season, cattle were generally grazed on shrubs or in paddocks further from the villages. As the availability of grasslands diminished with rice planting, cattle were grazed on paddy lines or along roads.

The majority of smallholder farmers reported that cattle grazed in paddy fields for several months after the rice harvest. In some areas devoid of alternative grazing fields, paddy fields were used for an extended time until the restart of rice field cultivation. Most smallholder farmers (84%) used both communal grazing (two-thirds of the time) and stall feeding (one-third of the time) to raise their cattle, others used only communal grazing (13%) or stall-feeding (3%). Just over a half (54%) of smallholder farmers in KC and under a half (45%) in PS had sold cattle in the last 12 months. Most of them reported that a higher price was the main reason, followed by a need for cash for household items and agriculture equipment. The majority of smallholder farmers (89%) had not purchased cattle in the study period. Most smallholder farmers in both provinces rated FMD (78%), other diseases including ticks (57%), availability of feed (45%), and sale prices (43%) as significant factors affecting livestock production and livelihoods in the communities. Shortage of labor (24%), input cost (16%), theft (15%) and slow growth (15%) were also listed as important factors but were reported by fewer smallholder farmers.

3.4 Knowledge of FMD and vaccination

The majority of farmers (95%) believed that they knew FMD symptoms very well (mouth and nose sores (blisters) foot sores and lameness), Further, they claimed they would recognize FMD if they saw FMD infected animals. Over three-quarters of farmers (79%) understood vaccination, and of those, 85% correctly identified the main purpose of vaccination is to protect animals against preventable disease. However, a small proportion of smallholder farmers thought vaccination could help in treating sick animals (11%) and believed that vaccination helped the animal gain weight (4%). The majority of smallholder farmers (87%) believed that healthy cattle should receive a vaccination. The study identified the village leader was the main source for vaccination and animal disease information reported by the majority of smallholder farmers (95%), followed by village animal health workers (VAHWs) (91%) and their neighbors (74%). Only 20% admitted that they received the same information from the district and provincial veterinarians and agriculture extension workers. Obtaining information from radio and television and the commune council was considered less or not important at all by the majority of smallholder farmers.

3.5 Experience of FMD vaccination

The majority of participating smallholder farmers (79%) admitted that they had not vaccinated their cattle against FMD in the past three years. Lack of willingness to pay for vaccination when cattle were still healthy was the most common reason reported for not vaccinating (by 35% of farmers), followed by never having received information about vaccination (34%), being too busy during the vaccination event (31%) or another reason as described (Table 3). Many smallholder farmers (22%) refused to answer the question. The results show that only 35% of smallholder farmers had vaccinated their cattle against FMD once every year during the previous three years, followed by two vaccinations in three years (13%), with a majority of farmers having vaccinated once only in three years (52%). Of those who had vaccinated cattle, none of them had vaccinated cattle every six months. When asked for the proportion of cattle of each household herd vaccinated each time, 62% had their entire herd vaccinated. The majority of farmers (85%) who had only some cattle vaccinated, reported that only adult cattle were vaccinated, while pregnant cows and calves did not receive any vaccination. When asked for reasons for not re-vaccinating their cattle every six months, nearly one-third (23%) of smallholder farmers in the study areas refused to answer the question.

The overall ranking of not re-vaccinating cattle every six months by reason (from 1 to 3 with one as the most important and three least important reason) found that many only vaccinated cattle when FMD vaccination

was free (44%), followed by the claim that no one had told them to re-vaccinate cattle every 6 months (17%), or that they thought FMD vaccination once every 12 months would be sufficient to protect cattle from FMD (17%). For vaccination services, the results showed that cattle were mostly vaccinated against FMD by the VAHWs in the village (77%), followed by the district veterinarians (48%) and VAHWs from other villages (24%). Most of the smallholder farmers admitted that FMD vaccination program was carried out through the government-subsidized vaccination (USD0.25), and none of them had paid full price for the FMD vaccination. The full minimum cost of FMD vaccination estimate by the interviewed farmers is USD3.00 for bi-annual FMD vaccination. Among the farmers who vaccinated their cattle against FMD, nearly one-third in both study areas revealed that their vaccinated cattle still became sick with FMD during the outbreak a few months after vaccination.

The majority of farmers (94%) could not distinguish the clinical disease conditions between sick vaccinated and unvaccinated cattle. Only a small proportion of farmers acknowledged that the clinical conditions of sick vaccinated cattle were less severe than those of sick unvaccinated cattle.

>Insert Table 3<

3.7 Experience of FMD and biosecurity practices

Regarding the collection and maintaining disease and vaccination records, the majority of smallholder farmers (95%) admitted that they have never maintained them and were not aware of the importance of maintaining them. In KC, 49% of interviewed farmers had experienced FMD during the previous 3 years, with a higher proportion of farmers 70% having experienced FMD in PS. The results indicate that the most recent FMD outbreak affected 46% and 85% of smallholder farmers in KC and PS, respectively. In PS, only 4% of smallholder farmers reported an FMD outbreak in 2011 and 11% in 2012, whereas in KC, while only 12% experienced an FMD outbreak in 2011, 42% experienced an outbreak in 2012. Overall, the morbidity rate in both age groups of cattle <3 years old and >3 years old was very similar in both provinces, with 32% in KC and 38% in PS. The mortality rate in cattle due to FMD was very low (0.45%) in both study areas. All farmers affected by FMD in 2013 were asked to report the proportion of sick cattle in each household herd. All cattle in the household herd were sick during the outbreak were reported by 61% of farmers in KC and 55% PS. The remaining farmers reported only some of their household herd were sick during the outbreak.

A majority (61%) of FMD affected farmers reported the occurrence of the disease to the VAHWs, followed by neighbors (53%), relatives (42%), and village leader (16%). Only 5% of farmers had communicated the occurrence of disease to the district and provincial veterinarians. Some farmers (11%) admitted that they have never reported the disease to anyone for the last three years. Overall, during the past outbreak, about three-quarters of smallholder farmers (74%) did not separate their infected cattle from the household herd. Farmers tethered infected cattle in the cowshed near the house (72%), under the house (60%), and under the trees surrounding the house (53%). Keeping infected cattle at relatives' houses was also reported by some farmers (19%). Of those who separated their infected cattle, only half separated them for the entire day, while others regroup them during the night. The majority of affected farmers (73%) believed that disease spread from the first sick cattle to others within the household herd. The study identified that the mean number of days that disease remained in each individual infected cattle was 14.2 days in KC and 17.3 days in PS. However, the mean number of days that disease remained in the herd (from the initial clinical signs until no more symptoms) was 28.5 days and 34.2 days in KC and PS, respectively.

3.8 Treatment and nursing of sick cattle

The study found that when animals became ill, particularly with FMD, treating lesions (fluid-filled or ruptured vesicles or blisters between the toes, on the heels, mouth, and tongue) and nursing sick cattle was the first preferred method of management reported by the majority of livestock smallholders. Nearly three-quarters of farmers (72%) requested their VAHWs to treat their sick cattle, while 53% and 16% preferred to treat sick cattle by themselves using traditional medicines and non-traditional medicines, respectively. The average cost of private treatment and nursing of each FMD infected cattle to full recovery was USD40.80, reported by affected farmers.

Other methods were also used reported by a small proportion of farmers (Table 3). Of those who used traditional methods to treat infected cattle, nearly two-thirds (70%) used several types of herbs, with some using engine oil (23%) aimed at cleaning lesions and deterring flies, and others (17%) walking infected cattle through the mud. For feeding, 65% of farmers reported that cut and carry was a common feeding method to feed infected cattle as foot lesions leave cattle lame and unable to walk.

All farmers experienced with FMD reported that the majority of their neighboring farmers' cattle (93%) were also sick with the same disease during the outbreaks. About half of those farmers (45%) claimed that their neighbor's cattle were infected with FMD before their cattle, with over a quarter (28%) believing their cattle became sick before their neighbor's cattle. However, nearly a quarter of farmers (22%) admitted that all cattle were sick at the same time during the FMD outbreak. The study revealed that all affected farmers had sought assistance from neighboring farmers and relatives during the FMD outbreak. About half (52%) of those treating infected cattle by themselves, reported they also sought assistance from local VAHWs, followed by one-third (33%) obtaining help from relatives, and some (18%) seeking assistance from friends or neighbors to restrain sick cattle so they could be treated.

Although one-third of farmers claimed they did not seek any help from other people, nearly half of the participating farmers (42%) acknowledged that they had assisted friends or neighbors during treatment. Of those who helped their friends to treat sick cattle, more than a half (57%) had assisted friends and neighbors before their cattle had become sick with FMD, with the remainder (43%) believing that they offered assistance after their cattle were infected with FMD.

For the treatment fee, approximately one-third of those who asked for animal health services reported that they had used their savings to pay the cost of treatment. When money was unavailable, they sold some rice and/or livestock (28%), followed by working for other people (22%), borrowing money from relatives (11%) and friends (6%) to pay for treatments. The study found that the great majority of farmers (89%) understood that the treatment cost was much higher than the actual cost of biannual FMD vaccination, while the remainder refused to answer the question. All of those who responded to the question acknowledged that they would change their disease management practices by participating in future vaccination programs. When asked about livestock trading during the outbreak, the majority of farmers (90%) reported that they did not buy or sell cattle and animal products during the FMD outbreak, with the remaining farmers refused to answer the question.

3.9 Perceptions of farmers on vaccination uptake and disease prevention

All respondents were asked to read through the multiple-choice questions with enumerators and choose the answers they thought most appropriately defined the activities that could help to mitigate the risk of spreading disease in their communities. Additional activities raised by farmers during the interview were also added if considered appropriate. The various activities that farmers thought would be able to improve the uptake of FMD vaccination in the future are displayed (Table 4). The perception of farmers was that the improvement of vaccination campaigns needed to continue in order to encourage vaccination uptake, followed by the increasing availability of vaccination programs, and provision of training on animal disease and vaccination. Stricter controls on the movement of sick animals and trading of sick or dead animals during the outbreaks were identified as important activities by many farmers, with other activities considered as important by less than one-third of farmers, as displayed (Table 4).

>Insert Table 4<

The main activities that farmers recognized as very important in helping reduce the risk of spreading diseases in their communities are provided in Table 5. Over half of the participating farmers recognized that animal vaccination, reporting of sick animals (new cases) and avoiding the trading of animals during the outbreak were very important in reducing the risk of disease spread within their communities. Just under half of the farmers believed that early separation of sick animals from the herd, having knowledge of the disease situation in surrounding villages, and avoiding contaminated feed and water, were very important activities.

>Insert Table 5<

3.10 Identification of potential risk factors associated with the uptake of FMD vaccination

In this study, a range of factors was investigated to assist in identifying the potential risk factors associated with the uptake of FMD vaccination in the study areas. Potential variables were grouped into three categories: (1) Farmer; age, education, and the number of household members; (2) Management; livestock management and husbandry skills; and (3) FMD; knowledge, experience and communication of FMD and the need for vaccination. The results of the univariable analysis of these potential factors are summarized in Tables 6, 7 and 8). Fifty variables were used to identify their association with the FMD vaccination program reported by the respondents.

The results for the Farmer category identified that only 4 variables were potential risk factors associated with the FMD vaccination uptake ($P [?]0.25$): farmers aged above 49 years old; farmers with formal education; being the primary decision-maker; and the household containing less than 3 members working with cattle (Table 6).

>Insert Table 6<

For the management category, 6 variables were identified as potential risk factors involved in the uptake of FMD vaccination ($P [?]0.25$), including farmers raised only cattle; farmers raised more than 3 cattle; cattle tethered under the house at day time; cattle tethered under the house at night time; cattle grazing at communal grazing ground; and bought cattle purchased recently (Table 7).

>Insert Table 7<

For the FMD category, 5 variables were identified as potential risk factors involved in the uptake of FMD vaccination ($P [?]0.25$). These included management and husbandry practices; the presence of the commune council as the main source of vaccination information; cattle had received FMD vaccination through vaccination campaign; VAHWs provide vaccination services, and FMD vaccinated cattle still became sick with FMD (Table 8).

>Insert Table 8<

3.11 Logistic regression model

A total of 5 variables (with $P [?]0.25$) were offered to the multivariable logistic regression model and retained in the final model (where variables had to have $P < 0.05$) as summarised (Table 9). The multivariable logistic regression analysis employing a backward elimination approach identified the commune council as the main source of vaccination information. Farmers reporting that VAHWs provide vaccination services for their cattle were 3 times more likely to have their cattle vaccinated against FMD than those who did not use VAHWs to vaccinate their cattle. Further, farmers reporting that the commune council was the main source of information on vaccination were less likely to have their cattle vaccinated against FMD. Similarly, farmers reporting that FMD vaccinated cattle still got sick with FMD were less likely to have their cattle vaccinated against FMD (absence of a protective factor). The Chi-square for the Hosmer and Lemeshow test $11x^2 = 3.24$, $df = 8$, $P = 0.918$, suggested that the multivariable logistic regression model was suitable.

>Insert Table 9<

4. Discussion

The study is one of the larger scale surveys of the knowledge, attitudes, and practices (KAP) of Cambodian smallholder livestock farmers on cattle health and production issues, providing information on FMD management and vaccination programs. The study intended to identify opportunities for improving the uptake of FMD vaccination and implementing biosecurity interventions in rural communities. The study identified that although smallholder farmers undertake a range of farming and off-farming activities, large ruminants contribute a large proportion of total household income (KC 30%; PS 25%) at the rural community level

(Ashley et al., 2018; Samkol et al., 2015) and deserve investments to mitigate disease risk, despite the majority of surveyed farmers still practicing the traditional method of cattle raising. Although all cattle in the household herd were tethered under the house during the night, as they are commonly permitted to graze on available pastures, paddy fields and shrubs or common grassland areas further from the village, there are ample opportunities for disease transmission within and between large ruminant village populations, as previously reported (Kawasaki, Young, Suon, Bush, & Windsor, 2015).

With most farmers using communal grazing method, the movement of large ruminants to communal grazing areas enables contact with animals from other locations, increasing the risk of contracting diseases, particularly FMD, as previously reported by other studies (Chamnanpood, Cleland, Baldock, & Gleeson, 1995; Cleland, Chamnanpood, Baldock, & Gleeson, 1995), and recently reviewed by (Blacksell et al., 2019). During FMD outbreaks, confining and feeding cattle on cut grasses reduces the likelihood of infection, with this practice proposed to reduce the risk of spread of FMD virus by reducing the direct contact between healthy and infected animals (Cleland, Baldock, Chamnanpood, & Gleeson, 1996). The growing of improved grass forage species has achieved positive production and socioeconomic outcomes (Stur et al., 2002; Young et al., 2014a; Young et al., 2014b) and if more widely adopted, a higher proportion of farmers employing cut and carry (stall feeding) to raise their animals will help reduce the risk of FMD transmission, improving rural livelihoods (Nampanya et al., 2015).

FMD was rated as a significant factor affecting livestock production by the surveyed farmers with most appearing to know and recognize FMD clinical signs and understand the main purpose of vaccination. Farmers revealed that people within the village were the most preferred persons to communicate new cases of diseases, indicating that the farmer disease communication network generally remained local. Local authorities such as district or provincial veterinarians were not acknowledged as important contact persons by the majority of farmers. This implies that VAHWs should have a more important role in assisting disease surveillance by receiving disease information from farmers and rapidly conveying this information to the district and provincial veterinary officials and local authorities for the disease intervention, as described by others (MacPhillamy et al., 2020; Stratton et al., 2015). However, as disease reporting is most effective when followed by a rapid disease response, particularly after the index case in the outbreak, strengthening of the role of the VAHW requires considerable effort in disease response training (MacPhillamy et al., 2020). Emergency disease reporting, investigation and response in Cambodia remain a critical weakness in FMD disease prevention and control (Blacksell et al., 2019; MacPhillamy et al., 2020), with the lack of urgency in FMD reporting indicating that many stakeholders tend to think FMD is not a serious disease due to low fatality rate (Sieng & Kerr, 2013).

The study found that three-quarters of interviewed farmers did not isolate the first FMD infected animal from the household herd, resulting in all cattle in the herd developing the disease. Of those who separated their ill animals, many of them only separated infected cattle during the day and usually regrouped them after the livestock returned from the grazing areas, as was identified in previous studies (Christley, Robinson, Lysons, & French, 2005; Gleeson, 2002; Sumption, Rweyemamu, & Wint, 2008). In rural communities, it is unlikely that smallholder farmers would have a safe alternative place at night to isolate the first infected animal and consider they have no choice but to keep all animals together at night. However, the poor knowledge and understanding of disease transmission and biosecurity practices of farmers identified in this and other studies indicate the enormous challenge facing animal health programs that aim to achieve FMD control in Cambodia and beyond (Blacksell et al., 2019; Kerr, Sieng, & Scoizec, 2012; Perry et al., 2002; Rast, Windsor, & Khounsy, 2010; Sieng & Kerr, 2013; Windsor et al., 2008; Young et al., 2012).

During the outbreaks, treatment was identified to be the first intervention preference for the majority of farmers, seeking treatment services from VAHWs (72%), with some more knowledgeable farmers commencing the treatment of FMD infected cattle by themselves (53%) with the assistance from relatives, friends, and neighbors. It is a Cambodian custom, especially in remote communities, to assist each other to restrain and treat infected cattle and this strong rural cultural practice is indicative of good communal relationships, although increases FMD transmission risk without improved hygiene practices. Most of the surveyed farmers

reported that the majority of neighboring farmers' cattle were also sick during the outbreak offering assistance before (57%) or after (43%) their cattle got infected with FMD.

Even though farmers appear to have some knowledge of FMD, it is disturbing that they were unaware that the risk of FMD spread via their movements, contaminated clothing, hands and feet equipment to livestock in other households is considerable. During an FMD outbreak, the social visits from family members, neighbors, and friends were reported to have contributed 25% of contacts with animals (Nielen et al., 1996). Several studies in developing countries revealed that the movement of people including traders, village chiefs, extension staff between villages and movement of animals from different villages in grazing areas is reported to be significant risk factors for the spread of FMD (Hunter, 1998; Kerr et al., 2012; Khounsy et al., 2008; Perry et al., 2002; Sumption et al., 2008).

The sale and purchase of infected animals were not reported by the majority of farmers in this study, although it is suspected that farmers preferred not to admit to this practice, particularly as compliance with restrictions on livestock trade and movements during the outbreaks is considered poor, with both infected and dead animals likely to be traded with local traders and local slaughterhouses. Trading of FMD infected animals during FMD outbreaks appears to be ongoing practice within rural communities in Cambodia, leading to the persistence of annual FMD outbreaks, with a morbidity rate exceeding 30% revealed in this study. High morbidity rates up to 74% were identified in an unvaccinated village in Lao PDR (Rast et al., 2010).

Previous studies with traders in Cambodia confirmed that farmers did sell sick livestock to avoid animals dying and to salvage some animal's value before death, and animal owners were more likely to sell sick animals, and more stock was available when diseases were prevalent in an area (Sieng, Hawkins, Madin, & Kerr, 2012; Young et al., 2014c). Interestingly, more than half of traders admitted that they had traded FMD infected animals, due to the low prices accepted by farmers for sick animals (Kerr et al., 2012; Sieng et al., 2012) although a survey of traders identified their preference for FMD vaccinated animals (Young et al., 2014c). Previous studies have consistently identified that the movement of infected animals and animal products are the most important factors increasing the spread of disease (Blacksell et al., 2019; Christley et al., 2005; Perry et al., 2002; Sumption et al., 2008; Young et al., 2014c). Lack of basic KAPs on disease transmission and biosecurity by farmers and other stakeholders at the village level remains a major concern for the veterinary authorities attempting to control a most infectious disease such as FMD.

In Cambodia, FMD control has relied only on ring vaccination around outbreaks. This study identified that over three-quarters of farmers (79%) had not vaccinated their cattle against FMD during the previous three years. Of those vaccinated, most cattle were vaccinated by VAHWs once every year or once in three years, and booster FMD vaccination had not been administered, as is recommended by vaccine manufacturers (Doel, 2003). This study found that only a small proportion of cattle in each village were vaccinated, suggesting that effective herd immunity was not achieved, as this would likely require at least 75% (Lombard & Schermbrucker, 1993) to 80% (Chamnanpood, Gleeson, & Robertson, 1993; Jori et al., 2009) of the population to be effectively vaccinated. Ring vaccination of all susceptible animals implemented with sanitary measures had been proposed as a means to reduce the spread and shorten the outbreak duration (Barteling & Vreeswijk, 1991). A case study of an FMD outbreak in Lao PDR (Rast et al., 2010) indicated that vaccinating the whole large ruminant population reduced the losses from FMD per animal by a factor of about four times compared to vaccinating only just over half the population.

In this study, the farmers identified that their most important reasons for not vaccinating were an unwillingness to pay for vaccination when their cattle were healthy and that they had not received information about vaccination. This finding indicates that the majority of farmers had a poor understanding of the usefulness and importance of vaccination, tend to rely entirely on free FMD vaccines supported by the veterinary authorities as a private FMD vaccination service was unavailable during the study period. As many farmers still perceive FMD as being far less important than other diseases due to the low mortality rate, private vaccination services may be more difficult to implement compared to other higher mortality diseases, such as Haemorrhagic Septicaemia (Kawasaki et al., 2015). Poorly delivered vaccination campaigns also contribute

to the low vaccination coverage even when the vaccine is available. This is not surprising, considering FMD vaccination delivery was based on government support, and the finding likely reflects those study villages may have been excluded from the list of villages vaccinated under the provincial FMD vaccination plan.

The multivariable logistic regression analysis indicates that age, education, number of household members livestock management and husbandry were not associated with the FMD vaccination practices of farmers. However, farmers reporting their cattle were vaccinated by a VAHW through a government-subsidized vaccination, indicated they were more likely to have their cattle vaccinated for FMD than those who did not avail themselves of VAHWs' services. The numerous issues arising with the delivery of large scale regional FMD vaccination programs over several years in the GMS have been identified and reported from Lao PDR (Blacksell et al., 2019; Nampanya, Khounsy, Abila, & Windsor, 2018).

Although FMD is not perceived as high mortality risk in most outbreaks (less than 1% in this study), the disease is highly infectious and debilitating, leading to significant economic losses for individual farming families, plus village, provincial and national levels (Nampanya et al., 2015; Young et al., 2014b; Young et al., 2012; Young et al., 2017). The economic impacts of FMD were identified in our study, with 8 of the participating farmer households having lost approximately one-third of their household herd during the most recent FMD outbreak. Several studies on the impact of FMD indicated that regular FMD outbreaks cause economic hardship for farmers due to loss of cattle body weight (Young et al., 2012), loss of production and/or death of affected animals (Muleme et al., 2012) and reduced sale value (Muleme et al., 2012; Perry et al., 2002; Young et al., 2012). Most of the interviewed farmers realized that the cost of treatment is much higher than the full fee bi-annual FMD vaccination, with some farmers likely wishing to pay for the private FMD vaccination services from the local VAHWs (Stratton et al., 2015), although FMD vaccines were rarely available.

However, a major reason contributing to the absence of private FMD vaccination services and the challenge of addressing the need for improved biosecurity change management (Young, Evans-Kocinski, Bush, & Windsor, 2015), is the likely farmer resistance following the long-standing practice of farmers receiving and expecting government-subsidized FMD vaccination. It is a challenging task for the DAHP and POAHP to convince farmers to change their attitudes and practices towards FMD vaccination and encourage them to participate and accept full fee-based FMD vaccination services for their cattle.

Thus, the quality of vaccination campaign delivery and extensive farmer training is essential in moving the rural Cambodian community to accept the inevitability of self-funding vaccination that can be delivered by private vaccination services in their communities. If the effectiveness of vaccination delivery can be improved and cattle can be protected during outbreaks, with adequate training to motivate farmers and overcome their resistance to change, the recognition that full fee bi-annual FMD vaccination is an important measure to protect cattle from FMD is perhaps achievable. As the study identified the average cost of treatment plus nursing a sick animal (USD41.00) was more than 10 times the cost of full fee bi-annual FMD vaccination (USD3.00), this information can form the basis of future extension programs on FMD management.

The feasibility of delivery and the potential success of TAD control measures, including vaccination programs, depends on the cooperation of farmers with local authorities at the village level, although provincial and national level service providers, international donors and stakeholders are also of relevance. A significant educational effort on vaccination and biosecurity is required to explain the benefits that disease risk management provides. Existing FMD control strategies, especially FMD vaccination delivery in Cambodia, require review, with appropriate surveillance and emergency response capabilities upgraded to enable provincial and central level services to enhance their abilities to reduce the occurrence of FMD outbreaks and improve the uptake of FMD vaccination. Full fee-based FMD vaccination services should be considered and introduced in rural communities by the veterinary authorities, although this requires that GDAHP and POAHP discuss this new concept with the VAHWs and village chiefs that will be essential in assisting extension workers in promotion of the vaccination campaign and ensuring farmers well understand the cost-benefits of full fee bi-annual FMD vaccination.

This field survey involved 300 smallholder farmers, although there is usually an issue with the accuracy of some responses as interviewed stakeholders may be reluctant to provide correct and true information if they know it is against the existing government or social policy. Further studies on the benefit and cost analysis of fee-based bi-annual FMD vaccination are required for the future improvement of FMD vaccination uptake as well as the FMD control program in Cambodia. Further, research questions to identify the cost and benefits of combined cattle health and production programs that include establishing forage with stall feeding, persistent vaccination and deworming programs, and importantly biosecurity including movement control, should be prioritized for future research study in Cambodia.

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Ethics statement

Approval to use the questionnaire was obtained from the University of New England Human Research Ethics Committees (Approval No. HE 13-242, 19 November 2013 – 19 November 2014). Informed consent was obtained from all individual participants included in the study. This article does not contain any studies with animals performed by any of the authors.

Conflict of interest statement

The authors declare that they have no conflicting interests.

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