Original Article

Monitoring of African horse sickness Virus-Specific Antibodies in horses, northeastern Thailand

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Abstract

African horse sickness (AHS) is caused by infection with the African horse sickness virus (AHSV). In March 2020, AHS was first reported in Thailand due to the importation of subclinically infected host animals, such as zebras. In this study, we conducted a serological survey for AHSV-specific antibodies across 21 horse farms in the northeastern provinces (n=3) of Thailand. A total of 600 serum samples were collected for cross-sectional (n = 292) and longitudinal serological monitoring (n = 308). A cross-sectional study was conducted in 2020, during which serum samples (n = 292) were collected and tested for AHS antibodies using the ELISA test. Our results showed that horses from non-vaccinated farms tested negative for the ELISA test, while horses from the vaccinated farm had positive AHS antibodies. From April to November 2020, following the first vaccination with a polyvalent vaccine (serotypes 1, 3, and 4), longitudinal serum samples (n = 91) were collected at 30, 90, and 180 days post-vaccination (dpv). From May to December 2021, after the second vaccination with the AHSV monovalent vaccine (serotype 1), serum samples (n=217) were collected at 0, 14, 30, 90, and 180 days post-vaccination. The results from the longitudinal study demonstrated that the live-attenuated AHS polyvalent vaccine (serotypes 1, 3, and 4) can induce a high AHS-antibody response lasting up to 6 months post-vaccination. The annual booster with monovalent vaccination (serotype 1) also produced a strong antibody response, which persisted up to 6 months post-vaccination. In summary, the information on serological monitoring of AHSV-specific antibodies in Thailand is useful for strategic planning to prevent and control the disease in the future.

Keywords: African horse sickness virus (AHSV), horse, monitoring, serology, Thailand

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Introduction

African horse sickness virus (AHSV) is non-contagious and belongs to the genus *Orbivirus* in the family *Reoviridae,* causing African horse sickness (AHS). The disease affects Equidae, including horses, ponies, European donkeys, and mules, while African donkeys and zebras are resistant to the severe effects of AHS infection. The AHSV is a vector-borne virus that is primarily transmitted by Culicoides midges; however, mosquitoes and/or ticks may also play a role (Thompson *et al.*, 2012). AHSV infection leads to primary viremia, where the virus replicates in the endothelium of lymphatic capillaries and regional lymph nodes. Then, secondary viremia occurs as the virus spreads to the capillary vessels of multiple organs, primarily the lungs and lymphoid organs (Chechet *et al.*, 2023). Viral replication typically occurs in the endothelial cells of blood vessels supplying the lungs, heart, liver, and spleen (Clift and Penrith, 2010). The clinical signs of the disease range from subclinical to severe, with mortality rates ranging from 0% to 100%. There are four forms of the disease: pulmonary, cardiac, fever, and mixed forms. The mixed form is when a horse exhibits both pulmonary and cardiac symptoms (Dennis *et al.*, 2019).

AHS regularly occurs in southern Africa, but the AHSV has also spread to North Africa, the Middle East, the Arabian Peninsula, Southwest Asia, and the Mediterranean region (Dennis *et al.*, 2019). There are nine antigenically distinct serotypes of AHSV that have been reported to date based on the virus capsid protein (VP2) (Potgieter *et al.*, 2015). Serotypes 1–8 have been identified exclusively in limited areas of sub-Saharan Africa. In contrast, serotype 9 is widespread and contributes to epidemics outside of Africa. Additionally, serotype 4 caused AHS outbreaks in Spain and Portugal from 1987 to 1990 (Mellor PS, 2004). During 2020-2021, AHSV serotype one has been reported in Thailand and Malaysia (Bunpapong *et al.*, 2021; Castillo-Olivares, 2021; Durán-Ferrer *et al.*, 2022). Especially Thailand, the country has strictly followed all the regulations in WOAH's Terrestrial Animal Health Code and successfully received AHS-free status approval from WOAH in March 2023 (WOAH, 2024).

Since AHS is an incurable disease, treatment options include appropriate animal husbandry practices. Practices in husbandry, including housing animals in vector-proof shelters before dusk, applying insect repellents, and encouraging natural predators of vectors such as fish, frogs, and bats, can contribute to preventive measures. However, the most effective approach for disease prevention and control is vaccination (Dennis *et al.*, 2019). Currently, the licensed vaccine is a polyvalent live-attenuated vaccine (LAV) designed for horses, mules, and donkeys, produced by Onderstepoort Biological Products (South Africa). There are two types of polyvalent live-attenuated vaccines available: 1) three AHSV serotypes (1, 3, and 4) and 2) the four AHSV serotypes (2, 6, 7, and 8) (Dennis *et al.*, 2019; Durán-Ferrer *et al.*, 2022). However, there is a concern regarding the potential risk of reverting to virulence, reassortment between field and vaccine strains, as well as the lack of differentiation between infected and vaccinated animals (DIVA) in disease-free areas (Dennis *et al.*, 2019). During the AHS outbreak in Thailand, live-attenuated vaccines, a polyvalent vaccine (serotypes 1, 3, and 4), and a monovalent vaccine (serotype 1) were used by the Department of Livestock Development to control the outbreaks. In this study, we conducted a cross-sectional serological monitoring for African Horse Sickness-specific antibodies in horse farms in the northeastern provinces of Thailand. The longitudinal serological monitoring of AHSV-specific antibodies in horses after the first and second mass vaccination with polyvalent vaccine (serotypes 1, 3, and 4) and monovalent vaccine (serotype 1) was also evaluated.

Materials and Methods

Serum Sample Collection: In this study, we collected serum samples from horses at participating horse farms located in the northeastern provinces of Thailand. Horse farms were selected based on the collaboration of horse farm owners, a history of AHS outbreaks, and AHS vaccination. In a cross-sectional serological study, a total of 292 horse serum samples were collected from 18 horse farms (A-R) (Table 1). In detail, 216 serum samples were collected from non-vaccinated horse farms (n=17) in Nakhon Ratchasima, Khon Khan, and Nong Bua Lum Poo provinces in 2020 (Farm A-Q). In addition, 76 serum samples were collected from one vaccinated horse farm (Farm R). In longitudinal serological monitoring, serum samples (n=91) were collected from 2 horse farms (farms S and T) after the 1st AHS vaccination with polyvalent vaccine (serotypes 1, 3, and 4) at 30, 90, and 180 days post-vaccination (dpv). In May 2021, the AHSV monovalent vaccine (Serotype 1) was used, with 13-month interval between the 1st polyvalent and 2nd monovalent vaccination. Then, serum samples (n = 217) were collected from three farms (farms S, T, and U) at 0, 14, 30, 90, and 180 days post-vaccination (dpv). It should be noted that the horses in farm U have never been vaccinated with the polyvalent vaccine. In this study, blood samples from horses were collected under the approval of the Khon Kaen University's animal usage and care protocol (IACUC-KKU-103/63) and with the consent of the horse farm owners by a team of collaborators at the Faculty of Veterinary Medicine, Khon Kaen University. Blood samples were collected by drawing 5-10 ml of blood from the jugular vein, which runs in the jugular groove between the sternomandibular and brachiocephalic muscles. Subsequently, blood samples were centrifuged to separate the serum, which was then stored at -20°C until use. The serum samples were sent by temperature-regulated transportation at 4°C to the Center of Excellence for Emerging and Re-Emerging Infectious Diseases in Animals (CUEIDAs) at Chulalongkorn University for an ELISA test.

Detection of African Horse Sickness Virus-Specific Antibodies: Serum samples were tested for the AHSV-specific antibodies by using an ELISA test kit (INgezim AHSV Compac Plus, Ingensa, Madrid, Spain). The assay was performed according to the instruction protocol of INgezim AHSV Compac Plus, Madrid, Spain. In brief, 100 µl of a 1:5 diluted serum sample was

dispensed into each well. In addition, 100 µL of positive and negative controls were added to the control wells and incubated at 37°C for 1 hour. The plate was washed 5 times, and 100 µl of conjugate was added to each well, incubated at 37°C for 30 minutes. The plate was then washed 5 times, and 100 µl of substrate was added to each well and incubated at room temperature for 10 minutes. Then, 100 µl of stop solution was added. The optical density (OD) of the sample was read with a spectrophotometer at 450 nm within 5 minutes after the addition of the stop solution. To interpret an ELISA result, the blocking percentage (BP) was calculated. Samples showing BP values <45% were considered negative, 45%-49% were considered as suspected, and >50% were considered positive for AHSV antibodies (Taesuji *et al.*, 2022).

Statistical Analysis: The ELISA result was calculated as the mean ± standard deviation (SD) of the blocking percentages. The differences in the blocking percentages were tested using analysis of variance (ANOVA), and $p < 0.05$ was considered statistically significant. Statistical analyses were conducted with GraphPad Prism 5.0 software (GraphPad Software Inc. La Jolla, CA, USA).

Result

In this study, serum samples were collected from horses with the verbal consent of the horse farm owners. A total of 600 serum samples were collected from 21 horse farms located in Nakhon Ratchasima (n=501), Khon Kaen (n=12), and Nong Bua Lamphu (n=87) (Figure 1). In detail, we performed a cross-sectional sample collection from 18 horse farms during the AHS outbreak in May 2020. Out of 292 serum samples, 216 samples were collected from 17 non-vaccinated horse farms, and 76 samples were collected from one vaccinated horse farm (Table 1 and Figure 2). For longitudinal sample collection, the serum samples were collected from 3 horse farms after 1st vaccination with polyvalent vaccine (Farms S and T) and 2nd vaccination with monovalent vaccine (Farms S, T, and U). In detail, 91 serum samples were collected from farms S and T after the 1st vaccination with polyvalent vaccine at day 30 (n=29), day 90 (n=30), and day 180 (n=32) post-vaccination (dpv). The 217 serum samples (n=217) were collected from farms S, T, and U after the 2nd vaccination with monovalent vaccine at day 0 (n=53), day 14 (n=53), day 30 (n=53), day 90 (n=17), and day 180 (n=41) post-vaccination (Figure 2).

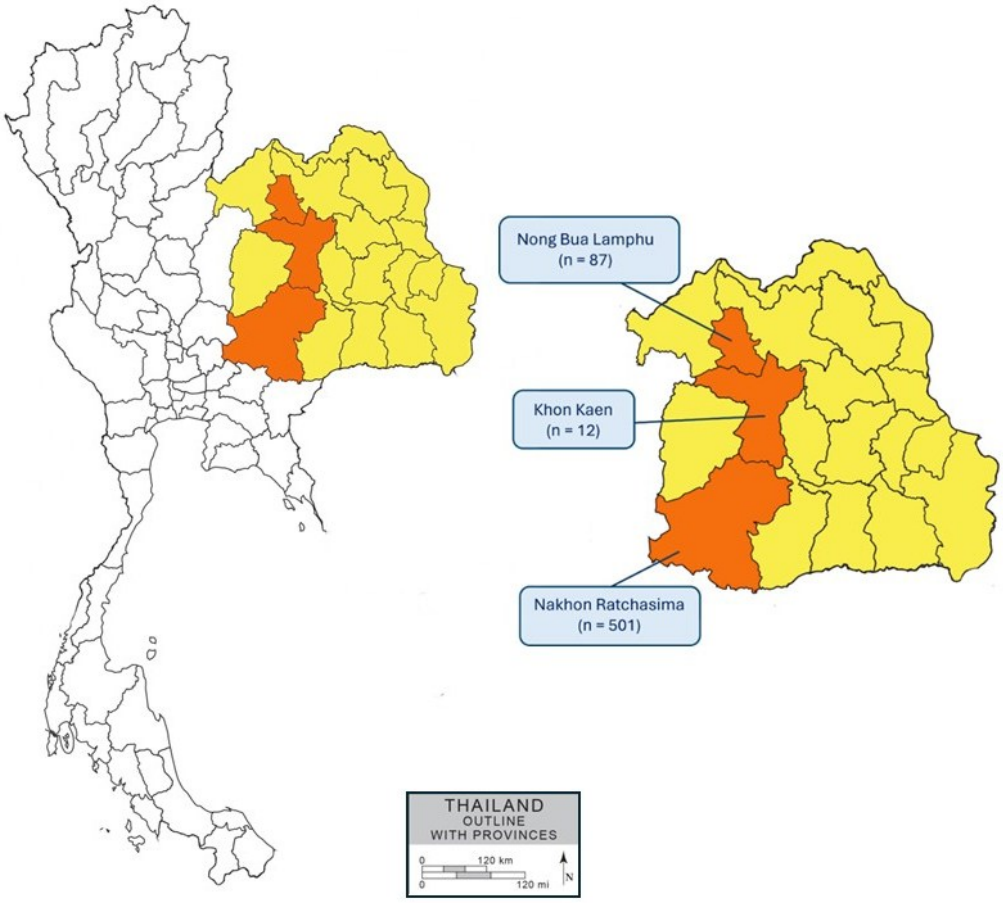

Figure 1 Map of Thailand and the provinces where horse farms were sampled in this study.
Note
Yellow = Northeastern part of Thailand
Orange = Location samples collected

Table 1 Details of the farm and the number of serum samples collected in this study

Farm	Location	Date	Status	# samples
Cross-section sample collection				
A	Nakhon Ratchasima	May-20	Non-vaccination	10
B	Nakhon Ratchasima	May-20	Non-vaccination	5
C	Nakhon Ratchasima	May-20	Non-vaccination	5
D	Nakhon Ratchasima	May-20	Non-vaccination	3
E	Nakhon Ratchasima	May-20	Non-vaccination	7
F	Nakhon Ratchasima	May-20	Non-vaccination	4
G	Nakhon Ratchasima	May-20	Non-vaccination	4
H	Nakhon Ratchasima	May-20	Non-vaccination	2
I	Nakhon Ratchasima	May-20	Non-vaccination	10
J	Nakhon Ratchasima	May-20	Non-vaccination	7
K	Nakhon Ratchasima	May-20	Non-vaccination	15
L	Nakhon Ratchasima	May-20	Non-vaccination	7
M	Nakhon Ratchasima	May-20	Non-vaccination	18
N	Nakhon Ratchasima	May-20	Non-vaccination	9
O	Nakhon Ratchasima	May-20	Non-vaccination	11
P	Khon Khan	Jun-20	Non-vaccination	12
Q	Nong bua Lum poo	May-20	Non-vaccination	87
R	Nakhon Ratchasima	May-20	Polyvalent vaccination	76
				292
Logitudinal sample collection (1st Vaccination, Polyvalent vaccine)				
S	Nakhon Ratchasima	May-Nov-20	Polyvalent vaccination	57
T	Nakhon Ratchasima	May-Nov-20	Polyvalent vaccination	34
U	Nakhon Ratchasima	-	-	-
Logitudinal sample collection (2nd Vacination, Monovalent vaccine)				
S	Nakhon Ratchasima	May-Nov-21	Monovalent vaccination	89
T	Nakhon Ratchasima	May-Nov-21	Monovalent vaccination	41
U	Nakhon Ratchasima	May-Dec-21	Monovalent vaccination	87
				308
				600

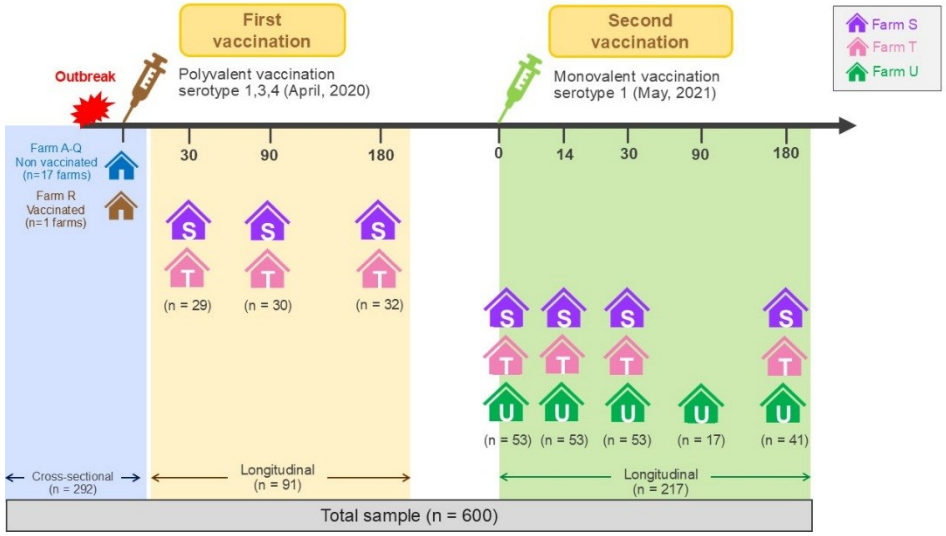

Figure 2 Schematic representation of cross-sectional and longitudinal sample collection from horse farms in this study.

Table 2 Details of longitudinal serum sample collection from farms S, T, and U after AHS vaccination (1st Polyvalent vaccination on Apr-Nov 2020 and 2nd Monovalent vaccination on May-Dec 2021)

Farm	# serum sample				
	0 dpv	**14 dpv**	**30 dpv**	**90 dpv**	**180 dpv**
AHS Polyvalent vaccination (Apr-Nov 20)					
S	-	-	18	19	20
T	-	-	11	11	12
U	-	-	-	-	-
			29	30	32
					Total 91
AHS Monovalent vaccination (May-Dec 21)					
S	23	23	23	-	20
T	12	12	12	-	5
U	18	18	18	17	16
	53	53	53	17	41
					Total 217

All serum samples were tested for AHSV-specific antibodies using an ELISA test kit. Our results showed that all serum samples (n=216) from 17 non-vaccinated horse farms were negative for AHSV antibodies (cut-off value < 50% blocking percentage). In contrast, one horse farm (farm R) had 76 serum samples, all of which were positive for AHSV antibodies with a cut-off value > 50% blocking percentage (Figure 3). For longitudinal serological monitoring, after polyvalent vaccine vaccination (serotypes 1, 3, and 4), we collected serum samples (n=91) at 30, 90, 180 days post-vaccination from 2 horse farms (Farm S and T). Our results showed that after vaccination with the polyvalent vaccine, the horses developed AHS-specific antibody titers and exhibited positive results by ELISA test (> 50% blocking percentage) from 30 days post-vaccination. Antibody titer statistically increased ($p < 0.05$) and then peaked at 90 days post-vaccination. The results also showed prolonged antibody titer and led to an ELISA test positive for 180 days post-vaccination (Figure 4 A).

In May 2021, the horse farms were vaccinated with the monovalent AHS vaccine (serotype 1). We conducted longitudinal serum sample collection in 3 horse farms (Farms S, T, and U). The 217 serum samples were collected from 3 horse farms at 0, 14, 30, 90, and 180 days post-vaccination. Our results showed that after AHSV monovalent vaccination (serotype 1), the antibody responses from horse farms S and T exhibited prolonged antibody titers and remained ELISA test positive from 0 to 180 dpv. It is noted that consistent ELISA test results from farms S and T were observed (Figure 4B). In addition, horse farm U was added to this study to monitor the antibody response after AHSV monovalent strain vaccination in a naïve herd (horse farm U did not receive AHS vaccination during the outbreak in 2020). Serum samples were collected at 0, 14, 30, 90, and 180 days post-vaccination. The results showed that after being vaccinated with the monovalent vaccine (serotype 1), the antibody titer began rising from 14 days post-vaccination and statistically increased ($p < 0.05$) at 30 days post-vaccination. The statistically significant ($p < 0.05$) differences between 30 and 90 dpv and 90 and 180 dpv were observed. In conclusion, in this horse farm, the antibody titer rose from 14 dpv and tested positive in the ELISA test from 30 to 180 dpv after a single dose of AHSV monovalent vaccine vaccination.

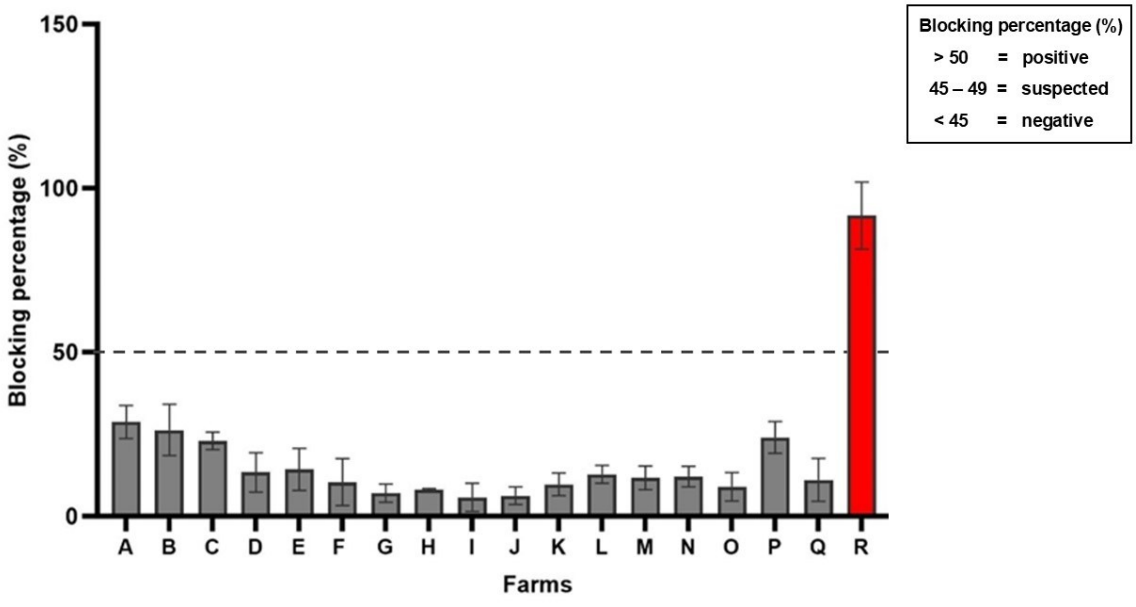

Figure 3 ELISA test results for AHSV-specific antibodies from cross-sectional sample collection (farms A - R) in this study.

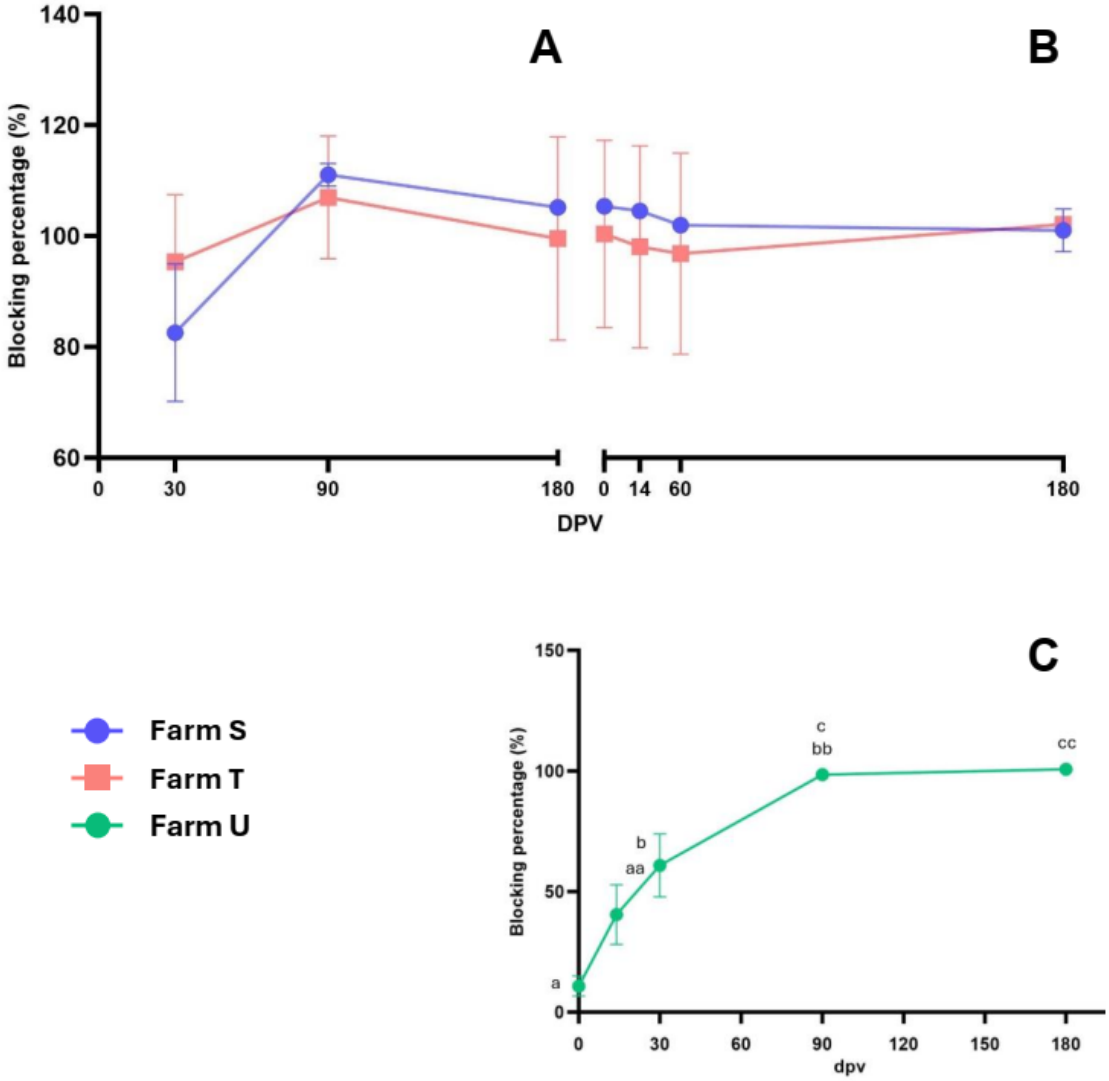

Figure 4 ELISA test results for AHSV-specific antibodies from longitudinal sample collection A) after 1st vaccination (polyvalent vaccine; farms S and T) at 30, 90, and 180 days post-vaccination, B) after 2nd vaccination (monvalent vaccine; farms S and T) at 14, 30, 90, and 180 days post-vaccination. C) after 2nd vaccination (monvalent vaccine; farm U) at 14, 30, 90, and 180 days post-vaccination.

Discussion

African horse sickness (AHS) is caused by infection with the African horse sickness virus (AHSV). In March 2020, AHS was first reported in Thailand due to the importation of subclinically infected host animals, such as zebras. During the epidemic, around 2,700 horses and 17 provinces were affected by the disease. The authorities implemented essential measures, including restrictions on animal movement, quarantine, disinfection, and the elimination of biting midges. During the AHS outbreak, mass vaccination with live-attenuated AHS vaccines was employed to prevent and control the disease. The serological monitoring was another approach to provide comprehensive information on an emerging disease outbreak.

In this study, after the African Horse Sickness (AHS) outbreak in March 2020, we conducted a cross-sectional serological survey in horse farms to monitor the AHSV-specific antibody response in AHS-vaccinated and non-vaccinated farms. As expected, all serum samples from 17 non-vaccinated horse farms were negative for AHSV antibodies (cut-off value < 50% blocking percentage). In contrast, one horse farm (farm R) was positive for AHSV antibodies with a cut-off value > 50% blocking percentage. Our findings align with a study previously reported in Thailand, which found that a single dose of live-attenuated AHS vaccination can stimulate high antibody titers sufficient for AHS prevention and control during outbreaks in Thailand (Kunanusont *et al.*, 2023).

In this study, we also conducted a longitudinal serological monitoring of AHS antibodies in 3 horse farms after vaccination with polyvalent vaccine (serotypes 1, 3, and 4) in 2020, followed by monovalent vaccine (serotype 1) in 2021. The results showed that after polyvalent vaccination, the antibody titer statistically increased ($p < 0.05$), then peaked at 90 days post-vaccination. The antibody titers are prolonged for 180 days post-vaccination. Then, after being boosted with monovalent vaccination (Farms S and T), the antibody titer showed prolonged positivity until 180 days post-vaccination. Similarly, another horse farm

(Farm U) vaccinated with only the monovalent vaccine showed an increase in the antibody titer from 14 days post-vaccination (dpv) and remained ELISA positive from 30 to 180 days post-vaccination (dpv) following a single dose of AHSV monovalent vaccination. It should be noted that all the serum samples in this study were also previously tested for AHSV antigens using Real-time RT-PCR to ensure that the horses had not been infected with AHSV (Data not shown). Therefore, the positive results for AHSV-specific antibodies from the ELISA test were attributed to vaccinations. Our results agreed with previous studies, which found that AHS antibody titers after vaccination could be observed for up to 180 days post-vaccination or 6 months post-vaccination (Kunanusont *et al.*, 2023). Another previous serological study in Thailand reported that AHS-naïve horses still required ≥ 2 vaccinations of the AHS vaccine and an annual booster vaccination to achieve high antibody titers (Chaiyabutr *et al.*, 2022). This may be due to the fact that the inactivated AHS vaccine causes antibody levels to decline between 5 to 7 months post-vaccination. Therefore, a booster vaccination after 6 months should be considered (Rodríguez *et al.*, 2020). Even though the antibodies could be induced by both live-attenuated and inactivated vaccination for up to 180 days. It should be noted that live-attenuated vaccines can stimulate both humoral and cell-mediated immune responses, whereas inactivated vaccines primarily induce humoral immunity and typically require more booster doses. A limitation of this study is that the AHS antibody titer was tracked for only 6 months (180 days). The actual duration of the antibody titer remains unknown. Moreover, this study only focused on the humeral (antibodies). Thus, serum neutralizing antibody test and cell-mediated should be further investigated.

In conclusion, this study revealed that vaccinated farms exhibited high antibody titers, whereas unvaccinated farms tested negative. Longitudinal serological monitoring demonstrated that both polyvalent and monovalent vaccines elicited sustained antibody responses for six months, supporting vaccination strategies that may require boosters approximately six months after initial vaccination to maintain immunity.

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Declarations

Ethics approval and consent to participate: This study was conducted under the approval of the Institute for Animal Care and Use Protocol of KKU University (IACUC-KKU-103/63).

Consent for publication: Not applicable

Data Availability Statement: The authors declare that the data supporting the findings of this study are available upon request from the first author.

Conflicting interests: All authors declare no conflicts of interest.

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