

METEOROLOGICAL FACTORS AND SWINE ERYSIPELAS TRANSMISSION IN SOUTHERN CHINA

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Swine erysipelas (SE) is one of the best-known and most serious diseases that affect domestic pigs, which is caused by *Erysipelothrix rhusiopathiae*. It is endemic in Nanning and has been circulating for decades, causing considerable economic losses. The aim of this study was to investigate the effect of meteorological-related variations on the epidemiology of swine erysipelas in Nanning City, a subtropical city of China. Data on monthly counts of reported swine erysipelas and climate data in Nanning are provided by the authorities over the period from 2006 to 2015. Cross-correlation analysis was applied to identify the lag effects of meteorological variables. A zero-inflated negative binomial (ZINB) regression model was used to evaluate the independent contribution of meteorological factors to SE transmission. After controlling seasonality, autocorrelation and lag effects, the results of the model indicated that Southern Oscillation Index (SOI) has a positive effect on SE transmission. Moreover, there is a positive correlation between monthly mean maximum temperature and relative humidity at 0-1 month lag and the number of cases. Furthermore, there is a positive association between the number of SE incidences and precipitation, with a lagged effect of 2 months. In contrast, monthly mean wind velocity negatively correlated with SE of the current month. These findings indicate that meteorological variables may play a significant role in SE transmission in southern China. Finally, more public health actions should be taken to prevent and control the increase of SE disease with consideration of local weather variations.

Key words: swine, swine erysipelas, Nanning, meteorological factors, zero-inflated negative binomial

INTRODUCTION

Swine erysipelas (SE) is caused by infection with *Erysipelothrix rhusiopathiae* (*E. rhusiopathiae*). Due to its high prevalence and economic impact, it is still a major concern for producers of domestic pigs all over the world [1]. *E. rhusiopathiae* is a facultative, non-spore-forming, non-acid fast, Gram-positive bacillus belonging to

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the genus *Erysipelothrix* [2]. Twenty-eight serotypes have been identified so far, and swine are susceptible to infection with no less than 15 of those serotypes [3, 4]. As *E. rhusiopathiae* infections have been found as a commensal or a pathogen in a wide variety of 50 distinct species (domestic pigs, turkeys, sheep, some fishes, rodents and birds), and these animals may possibly serve as natural reservoirs for the causative agent. The major reservoir of *E. rhusiopathiae* is generally believed to be domestic swine [2, 5]. *E. rhusiopathiae* may be transmitted to men, particularly to those who work or live in close contact with infected animals or pork products. In humans, this zoonotic agent may trigger cutaneous erysipeloid lesions, endocarditis and hematosepsis [5]. Thus, the presence of *E. rhusiopathiae* in determined swine populations does not only negatively affect farmers, but also food safety. Since SE outbreaks have increased again in pig populations in the Midwest United States and Japan, it has been regarded as a re-emerging disease which causes enormous economic losses in the swine industry [6, 7].

The ingestion of contaminated food or water, contact to feces or urine of infected pigs or to any objects that have previously been contaminated with the latter may trigger infection for pigs with *E. rhusiopathiae* via small skin lesions or environment, as well as by ticks, mites, and flies [2, 5]. Epidemics frequently occur in climates of high temperature and humidity. According to data provided by the Ministry of Agriculture of the People's Republic of China, 16,421 cases of SE have been reported in Mainland China between January 2006 and December 2015. Although morbidity and mortality of SE have decreased considerably since 1990s in China, SE cases have recently been observed to be on the rise again.

The need to explore how environmental risk factors affect SE transmission and disease onset, the demand for better possibilities of medical intervention is pushed by the public health services due to the threat posed by erysipelas to human health. Meteorological factors significantly affect the epidemiology of infectious diseases, and they can affect infectious diseases in a linear or non-linear fashion [8]. Researchers have focused on the influence of meteorological factors on the occurrence of the disease in men and animals [9-13], but to our knowledge, there is no study regarding an association between meteorological factors and SE in a subtropical monsoon climate region of southern China such as Nanning City. This study aimed to investigate the relationship between meteorological factors and SE using a zero-inflated negative binomial (ZINB) model, and find a potential indicator for future animal infectious disease risks in southern China. Furthermore, the results may provide valuable support for decision making regarding control and prevention of SE.

MATERIALS AND METHODS

Study area. The study area was Nanning, the capital city of Guangxi Province of Southern Mainland China. Nanning is located between 22° 13' E to 23° 32' E and 107° 45' N to 108° 51' N, with a typical subtropical monsoon climate, with hot and humid summers and warm and dry winters. The monthly mean temperature ranges

from 12.8 °C in winter to 28.2 °C in summer. Summer usually has heavy rains with an average annual precipitation measure between 1086.3 and 2754.5 mm. As the capital of Guangxi Province, Nanning is a medium-developed city and public health management is deficient. The typical humid subtropical monsoon climate and rich of water lead to frequently high temperatures and rainy weather. Pig breeding is an important economic branch in this region. All the meteorological and breeding conditions above are optimal for SE transmission.

There are three types of pig producing systems in China: commercial breeding, semi-intensive breeding farms and backyards that provide ‘free-ranging areas’. Due to Nanning being a less developed area, the majority of swine productions pertain to the categories of semi-intensive and backyard farming. Semi-intensive farming is usually practiced in medium equipped sheds made of concrete, wood fences or bricks, with the surfaces of tile floors or cement. Generally, they dispose of feeding and drainage equipment. Backyard farms raise free-range pigs or in very rudimental pens that lack feeding and drainage equipment. These farmers raise a small amount of pigs in order to meet the demands for meat and only parts of their income correspond to pig production.

Data collection. Monthly data on SE were obtained from Guangxi Aquatic Animal Husbandry and Veterinary Bureau. Data aggregated were available from January 2006 to December 2015. SE cases confirmed after clinical symptoms, histopathological and bacteriological results brought positive results. Three clinical forms of SE have been described in domestic pigs: acute (septicemia), subacute (urticaria), and chronic (arthritis, lymphadenitis, and endocarditis) [14]. According to the Law of the People’s Republic of China on Animal Epidemic Prevention, SE is a Class two animal infectious disease in China, veterinarians must report every case of SE to the local veterinary authorities or animal health supervision agencies.

With the purpose of identifying risk factors that possibly increase the risk for SE outbreaks in the study area, monthly meteorological data like mean temperature (T_{ave}), mean minimum temperature (T_{min}), mean maximum temperature (T_{max}), total rainfall (Rainfall), mean relative humidity (Hum) and mean wind velocity (Wind) from 2006 to 2015 in Nanning were retrieved from China Meteorological Data Sharing Service System (<http://cdc.cma.gov.cn/>). Mean meteorological values were calculated by averaging data based on the 9 basic surface meteorological observation stations in Nanning.

El Niño/Southern Oscillation (ENSO) is the most significant coupled ocean-atmosphere phenomenon affecting global climate variability and the climate in China [15]. We obtained the Southern Oscillation Index (SOI), which is computed using monthly mean sea-level pressure anomalies at Tahiti (French Polynesia) and Darwin (Australia). SOI was retrieved from the website of the Australian Bureau of Meteorology (<http://www.bom.gov.au/>). To control the seasonal variation of SE in

Nanning, the seasonal factor was extracted by using an additive model, which was introduced into the model [16].

Risk factor analysis model. Firstly, we used autocorrelation analysis to determine whether the current month's SE incidence was dependent on the incidence rates reported for the previous month. To this end, we applied the Ljung-Box Q test and calculated autocorrelation and partial autocorrelation coefficients (AC and PAC, respectively). In agreement with the results of this test, monthly SE case data could be included in the regression model as independent variables.

Analysis of Variance (ANOVA) was used to test the multi-colinearity of climate variables, which was further quantified by computing variance inflation factors (VIF) for each variable. $VIF > 10$ were considered to represent multi-colinear variables with a strong linear relationship [17]. Variable selection was identified by means of the corresponding Akaike information criterion (AIC) for the final model [18].

Cross-correlation analysis was applied to identify the lag effects of distinct meteorological factors on SE incidence. Significance of cross-correlation was estimated on the basis of $P < 0.05$ that, in turn, was calculated by Fisher's transformation (Z_r) of the cross-correlation coefficient (CCC) and standard errors of Z_r [19]. In this study, monthly SE case numbers constituted the response variables and the results of cross-correlation analysis determined the statistically significant independent variables which would be included in the regression model.

Data were tested for overdispersion with the Overdispersion test (O test) as has been proposed by Böhning in 1994 [20]. The statistic of O is an index of dispersion. Also, the temporal distribution of SE incidence contained a large proportion of zeroes due to no reported cases in some months during the study period. To deal with these distributional characteristics by 'excess' zeroes (non-occurrence), a ZINB regression model was applied for statistical analysis [21]. ZINB is a modified Poisson regression model that has been designed to deal with these two common issues, overdispersion and excess zeroes.

Finally, in order to evaluate the effectiveness of the model, an intraclass correlation analysis was performed to measure the consistency between actual and predicted data which adopted by the Intraclass Correlation Coefficient (ICC) [22]. Generally speaking, value of ICC is between 0 and 1, therefore it is believed that the data confirm good reliability when the ICC value is more than 0.75.

All data analyses were performed in Stata/SE 10.2 (StataCorp, College Station, TX, USA). Statistical significance was considered to be attained with P-values < 0.05 .

RESULTS

From January 2006 to December 2015, a total of 4,597 cases were reported. The temporal distribution of SE cases is depicted in Figure 1. These data suggest a seasonal

distribution of SE outbreaks and it can be seen that the incidence is particularly high in the summer months from May to August, while there were relatively few outbreaks reported over the rest of the year.

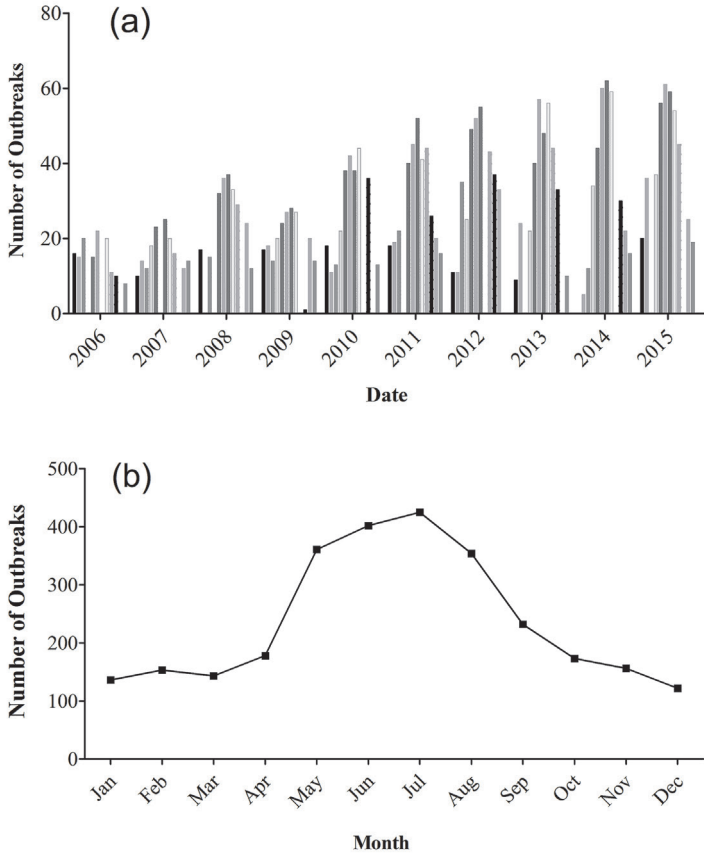


Figure 1. Temporal distribution of swine erysipelas outbreaks (Nanning, China, 2006-2015). **(a)** Long-term trend. **(b)** Seasonal distribution

Autocorrelation analysis showed that AC and PAC of first-order lag were greater than the coefficient corresponding to other orders, which means that SE outbreaks of the current month were affected by the outbreaks during the previous months (Table 1).

According to ANOVA, VIF of monthly mean temperature, mean minimum temperature and mean maximum temperature were far greater than 10, which means that there is high linear correlation between those factors (Table 2). According to the AIC criterion, mean maximum temperature was included in the final model.

Table 1. Autocorrelation and partial correlation of monthly swine erysipelas cases (2006-2015) in Nanning City, China

Lag	AC	PAC	QLB*	Df	p
1	0.561	0.561	34.593	1	<0.01
2	0.079	-0.343	35.293	2	<0.01
3	0.008	0.232	35.301	3	<0.01
4	-0.002	-0.170	35.301	4	<0.01
5	-0.003	0.125	35.302	5	<0.01
6	-0.003	-0.097	35.303	6	<0.01
7	-0.003	0.072	35.304	7	<0.01
8	-0.003	-0.057	35.305	8	<0.01

*Ljung-Box test statistic

Table 2. Multi-collinearity test of the model

Variable	VIF	1/VIF
T _{av} ^c	549.82	0.001819
T _{min}	221.11	0.004523
T _{max}	145.91	0.006853
Hum	3.72	0.269134
Rain	2.71	0.368344
Wind	2.16	0.462813
Season factor	1.72	0.580284

Abbreviations: VIF=Variance inflation factors for individual variables.

Through the cross-correlation analysis of the relation between monthly SE cases number and meteorological factors, it was found that the statistically significant factors included mean maximum temperature and mean relative humidity with 0 to 3 months lag, total rainfall with a lag of 2 to 3 months, and mean wind velocity as measured in the current month (Table 3). These statistically significant factors were introduced into the multivariable regression model by using a ZINB model.

Table 3. Cross-correlation coefficients between monthly swine erysipelas cases (January 2006-December 2015) and meteorological factors in Nanning City

Variable	Lag (in months)			
	0	1	2	3
Mean Maximum Temperature	0.390*	0.583*	0.671*	0.577*
Total Rainfall	-0.058	0.191	0.358*	0.460*
Mean Relative Humidity	0.129*	0.092*	0.292*	0.411*
Mean Wind Velocity	-0.196*	-0.049	0.018	0.032

*significant at P<0.05

Table 4. Results of multivariate analysis by using the ZINB model

Variables	Coeff.	Std. Err.	95% CI for β		Z	P	IRR	95% CI for IRR	
			Lower	Upper				Lower	Upper
Zero count model									
Lag case 1	-0.050	0.057	-0.162	0.063	-0.870	0.386			
Constant	-1.199	0.573	-2.322	-0.077	-2.090	0.036			
Negative binomial model									
Seasonal factor	0.045	0.051	-0.056	0.145	0.870	0.34	1.046	0.946	1.157
Lag case 1	0.002	0.003	0.001	0.002	3.97	<0.001	1.002	1.001	1.002
SOI	0.176	0.023	0.131	0.221	1.54	<0.001	1.192	1.083	1.301
Lag T _{max} 0	0.127	0.046	0.038	0.217	2.78	<0.001	1.135	1.088	1.182
Lag T _{max} 1	0.716	0.042	-0.756	2.188	0.95	<0.001	2.046	1.915	2.244
Lag Hum 0	0.249	0.08	0.092	0.407	3.11	<0.001	1.283	1.097	1.502
Lag Hum 1	0.313	0.173	-0.026	0.652	1.81	<0.001	1.368	0.974	1.920
Lag Rain 2	0.036	0.153	0.005	0.067	1.99	<0.001	1.037	0.946	1.126
Lag Wind 0	-1.878	0.608	-3.658	-0.098	-2.07	<0.001	0.153	0.026	0.907
Constant	-16.163	0.872	-18.875	-13.451	-16.53	<0.001			

Abbreviations: Coeff.=Coefficients; Std.Err.=Standard Error; CI=Confidence Interval; IRR=Incidence Rate Ratio; SOI=Southern Oscillation Index; Tmax=Monthly Mean Maximum Temperature; Hum=Monthly Mean Relative Humidity.

Notes: IRR is transformed from the coefficient, being equal to $exp(\hat{a})$. Lag 0/Lag 1/Lag 2: Records occurred current month and one-/two-month prior.

Table 4 shows the results of the final ZINB model. The statistic of O was 2190.90 ($P < 0.001$), which confirmed overdispersion. In the zero count model, there is a negative correlation between last month’s number of SE and the number of cases in the current month. Meanwhile, we also attempted to include monthly meteorological factors such as mean maximum temperature, mean relative humidity and rainfall, but there was no statistical significance of these variables. In the negative binomial model, the seasonal factor was not significant (0.05 level). With regards to SOI, we found Southern Oscillation to positively correlate with the epidemiology of SE. There was a negative correlation between the amount of reported SE outbreaks and mean wind velocity in the current month. In contrast, mean maximum temperature and mean relative humidity at lag of 0-1 month and rainfall at lag of 2 months mediated a positive effect on SE prevalence. We also calculated the incidence-rate ratios (IRR) with 95% CIs, and it can be seen that monthly mean maximum temperature of the prior month had the greatest impact on the disease epidemic. Ultimately, we analyzed true discrepancies between data predicted with the final multivariate model and reported case numbers and the fitness of the model (Figure 2). We calculated an ICC of 0.805 ($P < 0.001$) and this result indicates the reasonable consistence between the actual and predicted values, the model has a “goodness-of-fit”.

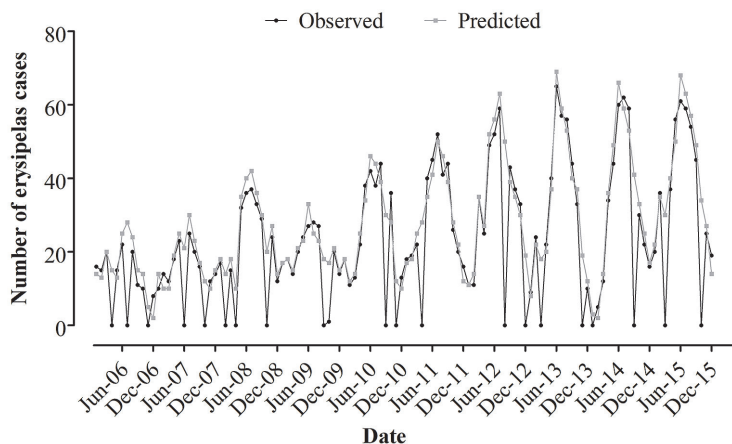


Figure 2. Monthly Observed and Predicted swine erysipelas cases from 2006-2015. The black line represents observed erysipelas cases and the gray line represents predicted cases. The vertical axis shows swine erysipelas cases and the abscissa axis denotes time in month from January 2006 to December 2015

DISCUSSION

Despite extensive vaccination, application of preventive hygiene measures and subsequent decrease of SE incidence in the course of the last two decades, SE is still one of the most common porcine infectious diseases in China [7]. However, according to the findings of this study, SE outbreaks increased again between 2009 and 2015. Furthermore, the prevalence exhibits distinctive significant seasonal variations, with most cases occurring from May to August, while there are next to no reports during some months. The fact that outbreaks are more frequently observed in summer compared to other seasons, may relate to the effect of climate on *E. rhusiopathiae* survival. Presumably, *E. rhusiopathiae* growth and replication is promoted by hot and humid conditions. This study examines the impacts of meteorological factors on SE disease using data collected in the Nanning City of southern China using the ZINB model.

The most common causes of infection with *E. rhusiopathiae* are: ingestion of contaminated food, water pollution and skin wounds. It has been demonstrated that sudden changes in nutrition, fatigue as well as other stressors facilitate infection [23]. To the best of our knowledge, this is the first controlled study that examines the effect of meteorological factors on the prevalence of SE. The results indicate that the number of SE cases positively correlates with SOI, monthly mean maximum temperature at 0-1 month lag, mean relative humidity at 0-1 month lag and rainfall at 2 months lag, while there is a negative correlation between SE case numbers and mean wind velocity of the current month.

The El Niño/Southern Oscillation (ENSO) phenomenon is a well-known climate fluctuation that causes irregular weather changes around the world [24]. Climate changes in the recent years, especially global warming, have already brought and will continue to bring about challenges to swine disease control and prevention [25]. Southern Oscillation has a strong influence on temperature, humidity and rainfall [24, 26]. SOI is an optimal index which can be used as a broad climatic index when the study area is relatively large [27]. The results clearly showed that increases in SOI yield elevated SE prevalence. The ENSO phenomenon did not only trigger extreme changes in weather, but reduced the immunity of swine [28]. Erysipelas is actually still not eradicated or eliminated from swine herds. It has been estimated that 30-50% of healthy swine harbor the organism in their oropharyngeal tonsils and other lymphoid tissue [14]. A weakened immune system may not only result in increased transmission but also in symptom onset.

According to the study, monthly mean maximum temperature and mean relative humidity have a positive impact on the epidemiology of SE prevalence. In addition, mean maximum temperature of the prior month had the greatest impact on prevalence. Global average temperature is warmer than it was just a couple of decades ago, thus warming is faster than expected [29]. Rising temperatures have also been observed in most regions of China including Nanning, with an increasing tendency of warming from southern to northern China [30]. High temperatures can affect the transmission of *E. rhusiopathiae* through some pathways. Laboratory evidence has shown the association between the survival and reproduction of *E. rhusiopathiae* and environmental temperature, with the optimal temperature ranging between 30 and 37°C [2, 31]. Also, the probability of food pollution may rise with ambient temperatures. In addition, higher temperatures can yield higher mosquito and other insect vector survival rates and thereby enhance *E. rhusiopathiae* transmission. Similarly, pathogen survival, contamination of food and water as well as vector populations may be elevated in seasons of high humidity. The amount of water vapor that air can hold increases with temperature. Furthermore, high temperatures and relative humidity suppress food intake, which lead to reduced body weight gains and poor immune functions [32]. These two risk factors combined with ENSO can harm pig immunity and susceptibility to disease, thereby affecting the disease transmission and increase the risk of *E. rhusiopathiae* infection.

Monthly total rainfall enhances the prevalence of SE. Heavy rainfall events can affect the frequency and level of contamination of drinking water [33]. Meanwhile, rainfall may cause the food to get wet which can promote the propagation of pathogens. High levels of precipitation increased the transmission of pathogens from animal to animal via the fecal-oral route, food or drinking water. Meanwhile, heavy rainfall promoted the pathogens transport through soil, and bacterial contamination of wells was discovered to coincide with periods of heavy rainfall [34]. Moreover, increased rainfall will create a more suitable environment for mosquitoes, flies and other hematophagus vectors. It

is known that *E. rhusiopathiae* resists for a long time in aquatic environments and thus easily survives long periods of rain [2].

Different factors, e.g., poor air conditions, heavy infestation with parasites and extreme temperatures may have predisposed pigs to contract SE. This study's findings show monthly mean wind velocity to be inversely associated with numbers of SE outbreaks in Nanning. In this context, wind may influence the transmission of this disease in different ways. High wind velocity can improve ventilation and air quality, which would reduce exposure to *E. rhusiopathiae*. Furthermore, it may affect the spread of arthropod borne diseases through active or passive dispersal of their vectors [35]. Additionally, it might contribute to the evaporation of humidity and heat radiation inside the barn.

At present, many pig farms have not suffered from SE outbreaks for many years, and awareness and preventive measures may have diminished among producers and veterinarians. Thus, most semi-intensive farms and backyard do not any longer vaccinate routinely against SE and only become aware of the threat when there are suspected or confirmed outbreaks in close geographical proximity. In addition, due to increased prevalence of swine influenza, swine fever, porcine reproductive and respiratory syndrome (PRRS) and other infectious diseases, large-scale use of antibiotics and even employment of growth-promoting antibiotics as feed-additive caused a serious decline in disease resistance of pigs and therefore lack of therapeutic options in major outbreaks. Quite a few small pig farms are "open" to the outside, access control and daily disinfection are not carried out in the majority of smaller pig farms [36]. Hence, this situation increases the probability of meteorological factors affecting SE prevalence.

However, this study also has some limitations which should be noted. When establishing the prediction model, only meteorological factors and SE number of cases were considered. Other potential socio-economic influence factors were not accounted for, such as pig rearing practices, pig management, live pig contact and movements. Also, lack of effective on-farm biosecurity and performance of only basic hygiene procedures leave pigs more susceptible to infectious diseases [37]. These factors may, however, affect the SE incidence and may therefore have decreased the predictive ability of the model. Nevertheless, while these factors are difficult to measure, meteorological factors are highly objective and readily available in an accurate and uninterrupted form [38]. Therefore, a model based on meteorological data will be better applicable and more easily transferable than potential models working with comparatively subjective, inaccurate and inconsecutive data. In general, values predicted with the final model agreed well with actual SE case numbers.

Furthermore, this study was based on official outbreak reports, but an outbreak was usually confirmed by local veterinaries when pigs manifested typical SE symptoms. Microbiological or serological tests were hardly conducted. Thus, there may have been an over-reporting of outbreaks owing to other diseases with similar clinical signs such as swine fever and porcine pasteurellosis. In addition, supervision of swine disease is

mainly passive and disease reporting is inadequate. Also, under-reporting is inevitable in studying infectious diseases, including swine erysipelas. Notified cases are those who have severe symptoms, and farmers often understate the number of cases attempting to avoid economic losses. This may be the reason of 'excess' zeroes (non-occurrence) as have been encountered in this study.

In brief, this study describes the relation between meteorological factors and SE outbreaks reported between 2006 and 2015 in the study area in southern China. The model developed for this work may constitute a valuable contribution to risk factor identification and outbreak prediction of SE. Our results help towards understanding the meteorological risk for SE and lag effect, which facilitates SE containment and epidemic awareness. In this line, identification of meteorological factors that slow down or speed up disease transmission would help health policy makers and veterinarians involved in SE control and prevention to make a decision support in disease control and risk management.

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Authors' contributions

HQ conceived and designed the experiments, performed the experiments, analysed the data, authored or reviewed drafts of the paper. XX and WS performed the experiments. BW and XH contributed materials/analysis tools, prepared figures and tables. LF and BY authored or reviewed drafts of the paper, approved the final draft. All authors read and approved the final manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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METEOROLOŠKI FAKTORI I TRANSMISIJA UZROČNIKA CRVENOG VETRA SVINJA U JUŽNOM REGIONU KINE

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Crveni vetar je jedna od najbolje poznatih infektivnih bolesti svinja, izazvana bakterijom *Erysipelothrix rhusiopathiae*. Enzootski se nalazi u regionu Nanning-a gde cirkuliše decenijama, izazivajući značajne ekonomske negativne efekte. Cilj studije je bio da se ispita efekat varijacije meteoroloških elemenata na epizootologiju crvenog vetra

u oblasti Nanning koji se nalazi u subtropskom pojasu Kine. Podaci o prijavljenim slučajevima oboljevanja kao i meteorološki podaci dobijeni su od zvaničnih institucija, a za period od 2006 do 2015. godine. Analizom unakrsne-korelacije, obavljena je identifikacija efekata meteoroloških promenljivih vrednosti. Statističkom metodom nulte negativne regresije, obavljena je evaluacija nezavisnog uticaja i doprinosa meteoroloških elemenata na transmisiju crvenog vetra. Posle obavljene kontrole sezonskog faktora, autokorelacije i efekata zaostajanja (*lag effect*), rezultati modela su ukazivali da Oscilatorni Indeks SOI ima pozitivan efekat na transmisiju crvenog vetra. Postoji i pozitivna korelacija između srednjih mesečnih vrednosti maksimalnih temperatura i relativne vlažnosti, sa efektom zaostajanja 0-1 i broja obolelih slučajeva. Nadalje, postoji pozitivna povezanost između učestalosti pojave crvenog vetra svinja i padavina, sa efektom zaostajanja od 2 meseca. Nasuprot tome, prosečna brzina vetra po mesecima, u negativnoj je korelaciji sa incidencijom crvenog vetra u toku datog meseca. Ovi rezultati ukazuju da promenljive vrednosti meteoroloških elemenata igraju značajnu ulogu u transmisiji crvenog vetra u regionu južne Kine. Konačno, imajući u vidu promenljive vrednosti meteoroloških elemenata, potrebno je da se preduzmu aktivnosti značajne za prevenciju i kontrolu povećanja broja slučajeva crvenog vetra.