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Research Article ***Open Access***

Application of Multivariate Logistic Regression and Decision Trees to Assess Factors Influencing Prevalence of Abortion and Stillbirth in Yankasa sheep

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SUMMARY

This study was carried out to assess factors influencing prevalence of abortion and stillbirth in Yankasa sheep using multivariate logistic regression and decision trees. 191 lambing records of ewes from a total of 50 traditional Yankasa sheep herders within Nasarawa South agro-ecological zone from the year 2020-2021 were utilized in the study. Sampling was restricted to only farmers that were able to give information on lamb, ram and ewe identification as well as occurrence of abortion, stillbirth (defined as a lamb born dead or dying within 24 hours after birth), lambing date or period, parity and number of foetuses. Three seasons of abortion or stillbirth were generated according to the month of the year: rainy season (from May to October), dry season (from February to April) and harmattan season (from November to January). The logit of the probability of an abortion or stillbirth was modelled using logistic regression assuming an asymptotic binomial distribution. The Chi-square goodness of fit test was performed to check if the multivariate logistic model fitted the data well (P>0.05). Chi-square automatic interaction detection (CHAID) algorithm was also employed to model prevalence of abortion or stillbirth. The chi-square test revealed that parity did not significantly (P>0.05) affect the prevalence of abortion. However, season of the year significantly (P<0.05) affected prevalence of abortion, which was higher in the harmattan (38.5%) compared to the rainy (11.5%) and dry season (16.5%), respectively. Parity and season of the year did not affect significantly (P>0.05) the prevalence of stillbirth. The binary logistic regression analysis showed that season affected

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significantly (P<0.05) the prevalence of abortion, especially in the harmattan period with a high odds ratio (4.539). This was also confirmed by the result of the CHAID analysis. The present information could be exploited in management practices to reduce to the incidence of abortion in order to improve the production level of the sheep farmers.

KEY WORDS: Logistic regression, classification tree, prevalence, abortion, stillbirth, sheep

INTRODUCTION

Yankasa sheep are a meat breed found in north and north central Nigeria (Mason, 1996). The breed is thought to have crossed with the West African Dwarf (Mason, 1996). Yankasa sheep are white with a black nose and around the eyes. They are polled or have small horns and semi-lop ears. They are well-adapted to the harsh environments of north and north central Nigeria.

Logistic regression allows the prediction of group membership from a set of categorical and/or continuous variables (x). Generally, the dependent variable is dichotomous and can take the value 1 (member of the group) with a probability of success y, or the value 0 (non-member) with probability of failure 1– y. The relationship between the dependent and independent variables is not a linear function. Instead, the logistic regression function is used, which is the logit transformation of y (Dossa *et al*., 2008).

A CHAID (Chi-squared Automatic Interaction Detection) tree is a decision tree algorithm used for classification and regression analysis. It is a non-parametric method that can handle both categorical and continuous data (Sakkaf, 2020). CHAID trees can be used to identify the most important factors that contribute to specific traits in animals. CHAID trees can also help identify interactions between different factors that affect the traits of interest. CHAID trees helps breeders to gain insights into the factors that influence specific traits and make more informed decisions about breeding (Abbas *et al*., 2021). They can focus on selecting animals with desirable traits and design breeding strategies that maximize the chances of producing offspring with those traits. Potential advantages of CHAID over classification and regression trees (CRT) is that CHAID tries to prevent overfitting from the start by only splitting nodes if there is a significant association, whereas CART (a variant of CRT) may easily overfit unless the tree is pruned. In CHAID, the selection of split variables and split points is less strongly confounded compared to CART. This can be advantageous in certain scenarios, especially when the trees are used for prediction. In Nigeria, sheep production plays an important role in the economic improvement of poor farmers and contributes to poverty alleviation (Yakubu *et al*., 2010). However, one of the major constraints to the successful development of the sheep industry is the menace of abortion and stillbirth. Abortion implies the expulsion of a fetus before full term and viability outside of the uterus. Antepartum death (stillbirth) is characterized by variable degrees of autolysis, accumulations of blood-tinged fluids in body cavities, soft autolytic lambneys, and variable degrees of liquefaction of the brain (Holler, 2012). These early losses are associated with a wide range of physiologic, nutritional, environmental, and noninfectious causes that often go unrecognized. Abortion in livestock herds at a level that significantly affects productivity is a common clinical problem

(Menzies, 2011). Despite ongoing research investigations to diagnose and evaluate the epidemiology of infectious factors that cause abortion, breeders are still being confronted with abortion continuously (Rafati *et al.,* 2010). Reproductive failure due to abortion disease remains a significant revenue drain in many ruminant livestock production systems (Simsek *et al.,* 2012). The prevalence of abortion and stillbirth is a great impediment to the sheep industry in Nigeria. The objective of the study therefore was to assess factors influencing prevalence of abortion and stillbirth in Yankasa sheep using multivariate logistic regression and decision trees.

MATERIALS AND METHODS

Location of study

The study was carried out in Lafia, Doma, Obi, Keana and Awe Local Government Areas (LGAs) of Nasarawa State. The five LGAs fall within Nasarawa South agro-ecological zone of the State.

Sampling procedure

A total of 50 Yankasa sheep farmers (10 per LGA) were randomly sampled.

Data collection

191 lambing records of ewes from a total of 50 traditional Yankasa sheep herders within Nasarawa South agro-ecological zone from the year 2020-2021 were utilized in the study. Sampling was restricted to only farmers that were able to give information on lamb, ram and ewe identification as well as occurrence of abortion, stillbirth (defined as lamb born dead or dying within 24hrs after birth), lambing date or period, parity and number of fetuses. Three seasons of abortion or stillbirth were generated according to the month of the year: rainy season (from May to October), dry season (from February to April) and harmattan season (from November to January).

Statistical analysis

The logit of the probability of an abortion or stillbirth was modelled using logistic regression assuming an asymptotic binomial distribution. The Chi-square goodness-of-fit test was performed to check if the multivariate logistic model fits the data well ($P>0.05$) (Hosmer and Lemeshow, 2000). CHAID algorithm was also employed to model prevalence of abortion or stillbirth using IBM-SPSS (2020) software.

RESULTS

Association between risk factors and the prevalence of abortion in Yankasa sheep in Nasarawa State using chi-square is presented in Table 1. Parity did not significantly ($P>0.05$) affect the incidence of abortion. However, season of the year significantly ($P<0.05$) affected prevalence of abortion. This was found to be higher in the harmattan (38.5%) compared to the rainy (11.5%) and dry season (16.5%), respectively.

Association between risk factors and the prevalence of stillbirth in Yankasa sheep in Nasarawa State using chi-square is presented in Table 2. Although the on the average, prevalence of stillbirth was higher in parity 5 (21.4%), this was not significantly ($P>0.05$) different from that of parity 4 (20.0%), 2

(18.4%), 3 (8.7%) and 1 (8.0%). Also, season of the year did not affect significantly (P>0.05) the prevalence of stillbirth.

Table 1.
The association between risk factors and the prevalence of abortion in Yankasa sheep

Parameters	No. of lambings	No. of abortions (%)	Chi-Square	P-value
Parity number				
1	50	6 (12.0)	4.871	0.432^{ns}
2	49	10 (20.4)		
3	46	8 (17.4)		
4	30	8 (26.7)		
5	14	4 (28.6)		
6	2	1 (50.0)		
Total	191	37 (19.4)		
Season				
Rainy	61	7 (11.5)	12.021	0.002**
Dry	91	15 (16.5)		
Harmattan	39	15 (38.5)		
Total	191	37 (19.4)		

** Significant at P<0.01; ns: Not significant, No.= number, P= probability, **%=** percentage

The result of the binary logistic regression analysis on the risk factors associated with the occurrence of abortion in Yankasa sheep is presented in Table 3. Parity was not significantly (P>0.05) associated with the occurrence of abortion. However, season affected significantly (P<0.05) the prevalence of abortion, especially in the harmattan period with a high odds ratio (4.539).

The result of the binary logistic regression analysis on the risk factors associated with the occurrence of stillbirth in Yankasa sheep is presented in Table 4. Parity did not significantly (P>0.05) influence the occurrence of stillbirth. Also, season did not affect significantly (P>0.05) the occurrence of stillbirth.

The result of the prediction of the occurrence of abortion using CHAID is presented in Figure 1. Out of the two risk factors, season significantly (P<0.05) influence the prevalence of abortion, and this manifested more in the harmattan period (38.5%) as revealed by terminal node 2. Resubstitution estimate = 0.194 while the standard error = 0.029.

Table 2.
The association between risk factors and the prevalence of stillbirth in Yankasa sheep

Parameters	No. of lambings	No. of stillbirths (%)	Chi-Square	P-value
Parity number				
1	50	4 (8.0)	5.310	0.379^{ns}
2	49	9 (18.4)		
3	46	4 (8.7)		
4	30	6 (20.0)		
5	14	3 (21.4)		
6	2	0 (0.0)		
Total	191	26 (13.6)		
Season				
Rainy	61	6 (9.8)	2.333	0.311^{ns}
Dry	91	12 (13.2)		
Harmattan	39	8 (20.5)		
Total	191	26 (13.6)		

** Significant at P<0.01; ns= Not significant, No.= Number, P= Probability, **%=** percentage

Table 3.
Risk factors associated with the occurrence of abortion in Yankasa sheep

	β	S.E.	Wald	Df	Sig.	Odds ratio	95% C.I.
Parity (ref: parity 1)			2.271	5	0.810		
Parity(2)	0.698	0.575	1.473	1	0.225	2.010	0.651-6.209
Parity(3)	0.445	0.595	0.557	1	0.455	1.560	0.486-5.011
Parity(4)	0.822	0.620	1.757	1	0.185	2.276	0.675-7.675
Parity(5)	0.635	0.771	0.678	1	0.410	1.887	0.416-8.555
Parity(6)	1.044	1.515	0.475	1	0.491	2.841	0.146-55.370
Season (ref: rainy season)			8.657	2	0.013		
Dry	0.473	0.496	0.910	1	0.340	1.605	0.607-4.241
Harmattan	1.513	0.544	7.731	1	0.005**	4.539	1.563-13.185
Constant	-2.557	0.579	19.490	1	0.000	0.078	

β = regression coefficient; Sig. = significant; **%=** percentage; S.E. = standard error; df = degree of freedom; C.I. = confidence interval; category; ** significant at P<0.01

Table 4.
Risk factors associated with the occurrence of stillbirth in Yankasa sheep

	β	S.E.	Wald	df	Sig.	Odds ratio	95% C.I.
Parity (ref: parity 1)			4.170	5	0.525		
Parity(2)	0.999	0.644	2.405	1	0.121	2.716	0.768-9.597
Parity(3)	0.094	0.741	0.016	1	0.899	1.099	0.257-4.697
Parity(4)	0.983	0.703	1.958	1	0.162	2.674	0.674-10.602
Parity(5)	0.921	0.859	1.149	1	0.284	2.512	0.466-13.538
Parity(6)	-19.238	28420.722	0.000	1	0.999	0.000	0.000-0.000
Season (ref: rainy season)			1.986	2	0.370		
Dry	0.417	0.538	0.600	1	0.438	1.518	0.528-4.361
Harmattan	0.864	0.614	1.982	1	0.159	2.373	0.713-7.903
Constant	-2.829	0.657	18.519	1	0.000	0.059	

β = regression coefficient; Sig. = significant; **%=** percentage; S.E. = standard error; df = degree of freedom; C.I. = confidence interval; ref = reference category

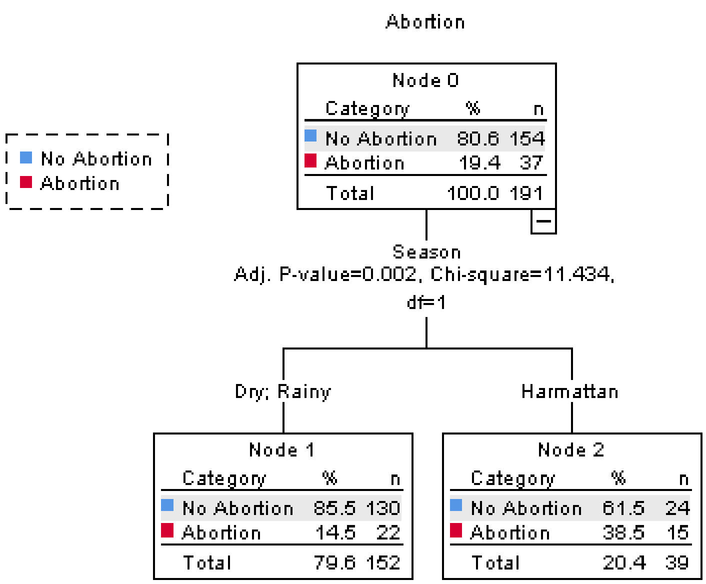

Figure 1: Prediction of abortion occurrence using CHAID model

DISCUSSION

The results are in agreement with the report of Alemayehu *et al.* (2021) who stated higher abortion in sheep during harmattan and the least during rainy. season. The reason for this that most sheep tested positive for causing agents such as *Brucella* spp, *C. burnetti*, *C abortus* amongst others were found to be higher during harmattan season. The result for parity is in accordance with the findings of Haileselassie *et al.* (2011) reported that parity number had no significant effect on the incidence of abortion in ruminants.

Infectious causes of abortion are most common after day 100 of pregnancy. While sporadic losses are variably attributed to handling procedures or movement, an abortion rate in excess of two per cent is suggestive of an infectious cause and veterinary investigation is essential at an early stage in ewes. Enzootic abortion of ewes, *Toxoplasma gondii* and Campylobacter species cause over 80 per cent of abortion outbreaks in the UK (NADIS, 2020).

However, the results of this current study is in disagreement with the reports of Steinbock *et al*. (2003); Hansen *et al*. (2004); Gundelach *et al*. (2009) who reported that parity has a significant difference in stillbirth parturition rate and reported a higher in first parity in cows than second parity. The stillbirth rate is highest for first kidding goats, partly because of a disproportion between the size of the kid and the pelvic area, which causes a difficult kidding and increases stillbirth parturition incidence (Steinbock *et al*., 2003; Hansen *et al*., 2004).

Chlamydophila abortus (the agent of enzootic abortion of ewes) is the most common cause of abortion in goats in the USA. In naive herds, up to 60% of pregnant does can abort or give birth to stillborn or weak lambs. Abortions can occur at any stage of pregnancy, but most are in the last month. Reproductive failure is usually the only sign of *C abortus* infection, but occasionally there is concurrent respiratory disease, polyarthritis, conjunctivitis, and retained placentas in the flock (Tibary, 2022). Earlier studies reported calving season in cows as a significant factor affecting the incidence of stillbirth parturition (Meyer *et al*., 2001; Johanson and Berger, 2003). Silva del Rıo *et al.* (2007) reported greater calf mortality occurred during the cold seasons compared with warmer seasons. The results of this study demonstrated that there is a significant association between lambing difficulty and stillbirth incidence in Yankasa sheep.

In the context of risk factor analysis in the current study, odds ratios are a statistical measure used to quantify the strength and direction of the association between a risk factor (or an independent variable) and an outcome (or a dependent variable). Odds ratios help us understand how the odds of a particular outcome change when a specific risk factor is present compared to when it is absent.

When the odds ratio is high, it typically indicates a strong positive association between the risk factor and the outcome. In other words, if the odds ratio is greater than 1, it suggests that the presence of the risk factor is associated with an increased likelihood of the outcome occurring. The higher the odds ratio, the stronger the association.

The present findings revealed that the season of the year is an important risk factor to be considered in a sheep enterprise. The prospects for increased productivity are based on efficient and sustainable exploitation of sheep inherent unique features, such as adaptability, ability to thrive in harsh environmental conditions, resistance to disease, etc. Herd managers should review lambing procedures with their veterinarian to ensure that proper timing and calving assistance techniques are used when providing assistance during parturition (Atashi, 2011). In addition, providing a good environment for heifers and does to minimize stress before parturition can reduce stillbirth incidence. The classification tree equally revealed that season was the most important factors that affect the incidence of abortion. This may be due to similarity in the differential power of each model. The risk value associated with the prediction of abortion in the present study appeared low which is an indication of better accuracy and reliability of prediction. this is similar with the findings of Gerjets *et al.* (2011). The tree diagram shows the occurrence of the abortion and vividly illustrates the structure of the risk factors and their complex interactions thereby making the findings easier to interpret, even to those with less statistical background (Harper, 2005).

Abortion and stillbirth in Yankasa sheep can lead to economic losses for farmers and have implications for herd health. Several factors can contribute to these reproductive problems in Yankasa sheep. Studies have shown a high prevalence of these pathogens in Yankasa sheep populations, which emphasize the need for proper management and control measures (Hassan, 2013).

It is noteworthy that appropriate precautions should

applicable in the field. Therefore, the present study on Yankasa sheep has significant implications for farmers and veterinary practitioners/herd health consultants as informed risk analysis is the key to successful decision making in relation to reproductive problem control on farms.

CONCLUSION

In the present study, the chi-square analysis, binary logistic regression model and the CHAID model showed that season is the most important risk factor affecting the prevalence of abortion in Yankasa sheep. However, parity and season did not have significant effects on stillbirth. The present information may therefore be exploited in management practices to reduce the incidence of abortion in order to improve the production level of the sheep farmers.

The potential implications of the findings on the prevalence of abortion and stillbirth in Yankasa sheep can have significant effects on the management and productivity of sheep flocks.

Based on the current findings, it is recommended that appropriate management and biosecurity measures must be put in place especially during the harmattan season to reduce the occurrence of abortion in sheep.

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