Indian Journal of Animal Sciences **86** (4): 431–435, April 2016/Article
https://doi.org/10.56093/ijans.v86i4.57731

Effect of non-genetic factors on voluntary and involuntary culling in Holstein Friesian crossbred cattle

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Received: 22 July 2015; Accepted: 25 August 2015

ABSTRACT

The present study focused on analysis of annual disposal pattern and identification of non-genetic factors affecting the incidence of culling in Holstein Friesian crossbred cattle. Data on disposal pattern of 1988 Karan Fries (Holstein Friesian crossbred) cows, spread over a period of 34 years (1978 to 2012), were utilized for the study. Culling was classified into 2 groups viz. voluntary (low milk production) and involuntary culling. Reasons of involuntary culling were categorized into locomotory problem (LP), poor health and weakness (PHW), teat and udder problem (TUP) and reproductive problem (RP). Logistic regression analysis was conducted to assess the effect of various non-genetic factors viz. number of normal lactations completed (NLC), calving type (CT), season of calving (SC) and period of calving (PC) on incidence of culling in various parities. The analysis of annual disposal pattern of the Karan Fries cows, revealed that the average annual replacement index, annual culling rate and annual disposal rate in the herd was 1.46, 24.40 and 29.80% per annum, respectively. Odd ratio estimates indicated that young calvers which did not complete atleast one normal lactation were 1.83 times more prone to culling because of PHW and were 0.95 and 0.33 times lesser prone to culling due to RP and LMP, respectively. Moreover, receiver operating characteristic (ROC) analysis indicated that the role of non-genetic factors in prediction of culling increased with parities and the logistic regression was efficient in predicting the incidence of parity wise culling, due to different involuntary causes, in Karan Fries cattle.

Key words: Culling, Disposal pattern, Karan Fries, Logistic regression

Culling and maintenance of herd dynamics are important components of breeding and management programme in an organized herd, as the animals are selected from a given lot of elite individuals. Response to selection and genetic gain will be lower if elite animals are culled in breeding programme. Though required levels of voluntary culling are desirable to improve the herd performance, it is the higher levels of involuntary culling which severely affect the herd structure and performance (Fetrow 1988, Weigel *et al.* 2003). An increase in involuntary culling affects the economically optimum scenario of a dairy herd and decreases its profitability by decreasing the net revenues (Rogers *et al.* 1988). It has been estimated that an optimum annual culling rate should be around 30.1% in cattle, of which voluntary culling should be higher around 50.0% (Dekkers 1991). Analysis and identification of non-genetic factors, which contribute significantly to involuntary culling of high yielding cows belonging to different parities, is of prime importance as this would enable the animal breeder to intervene and moderate the effect of such factors, thus optimizing herd structure and performance through effective management which in turn would maximize the genetic gain. The present study focuses on analysis of annual disposal pattern and effect of non-genetic factors on incidence of culling due to different disposal causes in Holstein Friesian crossbred cattle.

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MATERIALS AND METHODS

The present investigation was carried out on data of Karan Fries cows (Holstein Friesian crossbred cattle) maintained at ICAR-National Dairy Research Institute (ICAR-NDRI), Karnal, Haryana. Data on culling pattern of 1988 Karan Fries cows, spread over a period of 34 years (1978 to 2012), were utilized for the study. The cows completing at least first lactation were considered in the study. The culling was classified in to two groups viz. voluntary and involuntary culling. Voluntary culling of cows was performed on the basis of low milk production (LMP). Major reasons of involuntary culling were locomotory problem (LP), poor health and weakness (PHW), teat and udder problem (TUP) and reproductive problem (RP). Annual disposal pattern analysis was carried out by estimating annual culling rate, annual disposal rate and annual replacement index (ARI). ARI was estimated as number of heifer calving in a year/number of cows which left the herd (Ram and Tomar 1993).

Since the incidence of culling was considered as a binary trait, therefore, logistic regression analysis was conducted to assess the effect of various non-genetic factors affecting the incidence of culling. The non genetic factors considered for analysis were number of normal lactations completed (NLC), type of last calving - normal or abortion (CT), season of last calving (SC) and period of last calving (PC). The model used for logistic regression analysis was $C_{ijklm} = \mu + NLC_j + CT_j + SC_k + PC_l + e_{ijklm}$ where, C_{ijklm} , culling code (LP, PHW, LMP, TUP and RP) of the mth cow calved in the lth period and kth season having jth type of calving and with ith number of normal lactations upto disposal; μ , overall mean effect; NLC_i, ith number of normal lactations completed upto disposal; SC_k, kth season of last calving before disposal; PC_l , lth period of last calving before disposal; CT_j, type of last calving before disposal; 1 for normal and 2 for abnormal calving; e_{ijklm}, error. This dichotomous model in logistic form can be represented as follows:

$$ln\left[\frac{p}{1\text{-}p}\right] = \beta_0 + \sum_{j=1}^{c} \beta_j X_j + e$$

where, *ln*, natural logarithm; *p*, probability that the dependent variable equals a case; β_0, intercept from the linear regression equation (the value of the criterion when the predictor is equal to zero); $\beta_j X_j$, regression coefficient multiplied by some value of the predictor. Step wise logistic regression analysis was carried out in SAS 9.3 (SAS 2011) and the best fit model was adjudged from coefficient of determination (R^2), Akaike information criteria (AIC) (Akaike 1974) and Schwarz information criteria (SC) values (Schwarz 1978). Since R^2 is not considered as an ideal model fitness criterion, when the dependent variable is binary or dichotomous; receiver operating characteristic (ROC) curve analysis was carried out, as ROC indicates the accuracy of the logistic regression model. The ROC curve was generated by plotting sensitivity (Y-axis) against 1– specificity (X-axis) (Metz 1978).

RESULTS AND DISCUSSION

Effect of non-genetic factors on likelihood of culling due to different causes along with odd ratio estimates are detailed in Table 1. Fitness criteria of all the logistic regression models attempted for prediction of disposal causes are indicated in Table 2 and model with highest estimate of area under the curve (AUC) for ROC curve are indicated in Fig. 1.

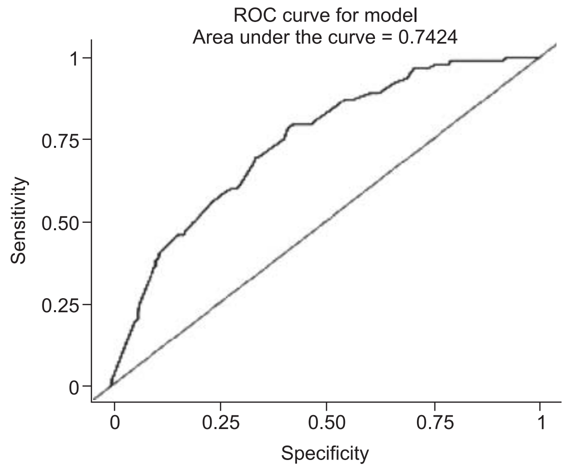
Annual disposal pattern: The analysis of annual disposal pattern of the Karan Fries cows, revealed that the average annual replacement index, annual culling rate and annual disposal rate in the herd was 1.46, 24.40 and 29.80% per annum, respectively. Moreover, the total proportion of disposal due to LMP, RP, TUP, LP, PHW and miscellaneous culling reasons were 14.51, 12.88, 17.52, 12.64, 9.57 and 13.79% respectively, which indicated that out of the total culled cows, involuntary culling (RP, TUP, LP, PHW and miscellaneous culling reasons) accounted for 66.40% with teat udder problem accounting for the highest number of cases followed by reproductive problem. The average annual mortality was around 5.40% and overall disposal due to mortality from 1981 to 2010 revealed toxemia (24.92%). Respiratory system problems (21.45%) were the major causes of mortality. Trend of replacement index did not vary greatly during the period of study and the highest replacement index of 4.91 was observed during 1982, due to higher proportion of heifer calvings in comparison to total adult cows disposed. Highest disposal (45.19%) and culling (38.46%) was noticed during the year 2007; of the total culling cases, teat and udder problem accounted for the highest proportion of cases (26.24%) followed by locomotory problem (25.00%), reproductive problem (15.00%) and poor health and weakness (6.25%). The annual culling pattern was similar to the disposal pattern from 1981 to 2010, indicating less change in mortality rate during the period of thirty years. Records on cows and heifers in NDRI herd of crossbred cattle analyzed by Kulkarni and Sethi (1990) revealed that 24.3% of Karan Fries cows were culled during 1981 to 1986 and the percentage of cows culled for low production, reproductive disorders and health problems was 11.0, 4.5 and 8.8, respectively. Singh and Gurnani (2004) found that the mortality trend in Karan Fries cattle ranged from 7.76 to 25.00%, over a period of six years (1986 to 1991), further, they reported poor health as the major reason of culling (27.11% of total culling), followed by reproductive disorders (23.24%) and locomotive problems (18.49%). Pinedo *et al*. (2010) reported annualized live culling rate and death rate in Holstein cows were 25.1 and 6.6%, respectively; their study also revealed mortality as the primary disposal cause (20.6%), followed by reproductive problem (17.7%), injury (14.3%) and low production and mastitis (both 12.1%).

Effect of various non-genetic factors on likelihood of culling: In first parity cows, culling due to PHW and RP was significantly (P<0.01) influenced by NLC. First parity cows were more prone to culling because of PHW and the probability of culling was 1.831 times higher in cows which did not have a normal first lactation in comparison to those cows that had completed their first lactation. The likelihood of culling due to RP was lower in cows which did not have any normal lactation. The estimates of fitness criteria of all the models for prediction of disposal causes indicated were not on higher side. The ROC analysis for logistic regression model for LMP, LP, PHW, TUP and RP indicated a fair level of accuracy of 64.80, 58.35, 69.60, 74.24 and 66.20%, respectively.

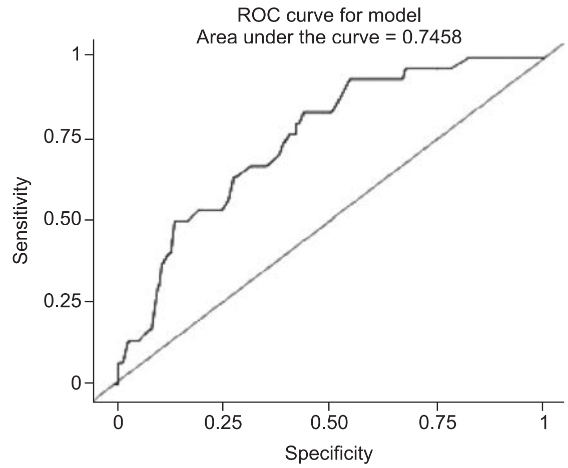
Table 1. Influence of non-genetic factors on likelihood of culling due to different causes of Karan Fries cows in different parities (expressed in terms of odds ratio)

Effect	Parity																			
	LMP				LP				PHW				RP				TUP			
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th
NLC	NS	NS	**	NS	NS	NS	NS	NS	**	NS	NS	NS	**	**	NS	NS	NS	NS	NS	NS
0	0.386	<0.001	<0.001	—	0.819	3.906	>999.99	—	2.831	<0.001	<0.001	—	0.059	<0.001	<0.001	—	0.677	1.337	<0.001	—
1	1.000	0.835	5.350	<0.001	1.000	0.697	1.942	<0.001	1.000	2.382	<0.001	15.458	1.000	0.242	<0.001	<0.001	1.000	0.491	<0.001	<0.001
2	—	1.000	2.692	<0.001	—	1.000	0.474	<0.001	—	1.000	1.106	<0.001	—	1.000	0.254	<0.001	—	1.000	1.593	4.164
3	—	—	1.000	0.906	—	—	1.000	1.179	—	—	1.000	0.958	—	—	1.000	0.091	—	—	1.000	0.738
4	—	—	—	1.000	—	—	—	1.000	—	—	—	1.000	—	—	—	1.000	—	—	—	1.000
CT	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	**	NS	NS	NS	NS
Normal	0.773	0.648	0.813	2.092	1.124	2.689	0.846	>999.99	1.295	1.304	2.338	0.429	0.571	0.707	0.434	0.145	1.298	1.079	0.647	0.852
Abnormal	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
SC	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Winter	0.820	1.174	1.631	0.453	1.256	0.935	1.318	1.880	1.787	0.852	0.611	5.667	1.551	0.881	0.712	1.041	0.725	0.866	0.725	0.731
Summer	1.377	1.251	1.462	0.534	1.011	0.464	1.346	0.615	1.651	2.783	1.021	7.665	0.910	0.884	0.524	0.547	0.608	1.063	0.519	0.877
Rainy	0.983	1.170	1.393	1.651	1.507	1.269	2.115	1.545	1.093	1.208	1.066	1.628	0.550	0.796	0.700	0.540	1.381	1.091	1.199	0.666
Autumn	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
PC	NS	**	NS	NS	NS	NS	NS	NS	NS	*	NS	NS	**	*	NS	NS	*	*	**	NS
1988–1992	1.365	0.385**	0.832	10.730	0.395	2.222	<0.001	<0.001	4.518	1.440	7.794	<0.001	2.710	2.062	<0.001	234.520	1.242	0.371	0.742	<0.001
1993–1996	0.549	2.045	1.597	0.770	0.936	1.201	2.211	0.948	3.652	5.817	2.940	0.834	0.992	3.611	0.444	13.754	1.254	0.376	0.537	1.706
1997–2000	0.696	1.746	1.097	4.078	0.920	0.880	1.657	0.197	5.016	1.294	1.413	1.086	0.727	0.941	0.412	7.227	2.624	1.442	3.081	2.556
2001–2004	1.284	3.568**	1.027	1.678	0.719	0.925	2.949	0.737	5.637	2.903	4.377	2.146	1.058	2.322	1.563	12.411	0.442	0.714	0.567	0.379
2005–2008	0.475	2.712*	0.716	0.838	1.053	0.460	1.132	0.429	5.005	4.531	2.730	0.699	0.645	1.442	0.868	18.880	1.731	1.462	1.962	2.820
2009–2013	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

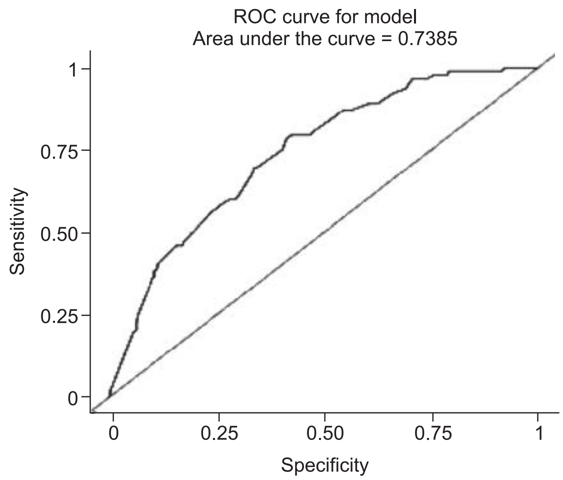
*significant at P<0.05; ** highly significant at P<0.01; — subclass effect not considered for analysis.



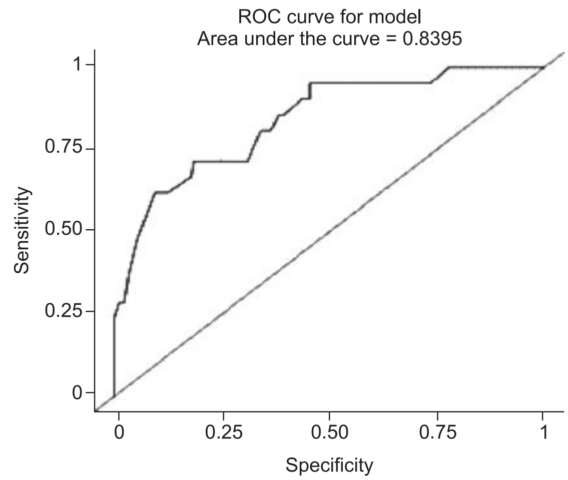
(a) First parity: Reproductive problem (RP)



(b) Second parity: Poor health and weakness (PHW)



(c) Third parity: Reproductive problem (RP)



(d) Fourth parity: Reproductive problem (RP)

Fig. 1. Logistic regression model (used for different disposal causes of cows in different parities) with highest estimates of area under the curve.

In the second parity cows, period of calving had significant influence on culling due to LMP, PHW, RP and TUP, indicating improvement in managemental practices across years in decreasing culling due to the causes considered in the present study. Culling due to RP was also significantly ($P<0.01$) influenced by the NLC and likelihood of culling due to RP increased with the increasing normal lactations and cows with lesser normal lactations during their herd life were least prone to culling due to RP. Fitness criteria estimates of all the logistic regression models attempted in the study did not reveal good fit, with respect to AIC, SC and R^2. The ROC curve for logistic regression model for LMP, LP, PHW, TUP and RP indicated fair levels of accuracy viz. 67.28, 66.88, 74.58, 70.68 and 65.94%, respectively.

Odd ratio estimates indicated that cows which had lesser NLC upto their third parity had greater likelihood of culling due to LMP, as LMP was significantly ($P<0.01$) affected by NLC. Period of calving had significant ($P<0.01$) influence on culling due to TUP and odd ratio estimate had an overall increasing trend which may be due to the increase in frequency of high yielders in the herd. All the logistic regression models had low R^2; AIC and SC values of intercept with covariates. However, the estimate of area under the ROC curve for logistic regression model for LMP, LP, PHW, TUP and RP indicated a fair level of accuracy of 65.75, 68.14, 69.78, 73.85 and 72.31%, respectively.

The effect of non-genetic factors on culling of cows which had completed four parities was not significant except in case of culling due to RP, in which the effect of CT was highly significant, as aborted calvings may have subsequently resulted in reproductive problems in the cows. Moreover, the estimates of AIC and SC were not superior for intercept with covariates model in comparison to the intercept only model. Though the R^2 of all the logistic regression models attempted were low; however, the estimates of area under the ROC curve for logistic regression model for LMP, LP, PHW, TUP and RP were 75.17, 71.96, 75.41, 83.95 and 68.14%, respectively. The ROC curve estimates indicated that all models had fair level of accuracy with respect to the prediction of the disposal outcome.

Earlier, Durr *et al.* (1999) reported that parity had a significant effect on involuntary culling and the proportion of cows culled mainly because of reproductive problems,

Table 2. Fitness criteria of logistic regression model for prediction of disposal due to LMP, LP, PHW, RP and TUP of cows in different parities

Parity	Fitness criterion	LMP Intercept only	LMP Intercept and Covariate	LP Intercept only	LP Intercept and Covariate	PHW Intercept only	PHW Intercept and Covariate	RP Intercept only	RP Intercept and Covariate	TUP Intercept only	TUP Intercept and Covariate
1	AIC	354.64	359.31	461.01	472.85	436.81	425.98	493.16	452.49	399.60	400.61
	SC	358.90	406.25	465.28	519.79	441.08	472.92	497.43	499.43	403.87	447.55
	–2 Log L	352.64	337.31	459.01	450.85	434.81	403.98	491.16	430.49	397.60	378.61
	R Square	2.87%		1.50%		5.68%		10.80%		3.54%	
2	AIC	488.97	480.41	334.68	338.89	228.35	229.24	375.49	366.22	409.04	412.24
	SC	493.17	530.87	338.89	389.34	232.55	279.69	379.69	416.68	413.24	462.69
	–2 Log L	486.97	456.41	332.68	314.89	226.35	205.24	373.49	342.22	407.04	388.24
	R-Square	5.99%		3.53%		4.17%		6.12%		3.73%	
3	AIC	372.85	374.26	238.00	243.18	149.55	164.95	229.35	228.65	299.30	294.71
	SC	376.70	424.38	241.85	293.30	153.41	215.06	233.20	278.77	303.15	344.82
	–2 Log L	370.85	348.26	236.00	217.18	147.55	138.95	227.35	202.65	297.30	268.71
	R-Square	6.27%		5.25%		2.43%		6.83%		7.87%	
4	AIC	156.72	159.07	153.10	159.90	120.68	131.55	133.62	123.56	176.67	189.62
	SC	159.95	201.15	156.34	201.97	123.91	173.63	136.86	165.63	179.91	231.70
	–2 Log L	154.72	133.07	151.10	133.90	118.68	105.55	131.62	97.56	174.67	163.62
	R-Square	10.87%		8.74%		6.74%		16.57%		5.71%	

LMP, low milk production; LP, locomotory problem; PHW, poor health and weakness; RP, reproductive problem; TUP, teat and udder problem.

mastitis and feet and leg problems increased with parity. Pinedo *et al.* (2010) also reported reproductive problems as most often disposal code in first and second parity. They also found that period of caving had highly significant ($P<0.01$) influence on culling due to RP and significant ($P<0.05$) influence on culling due to TUP. Durr *et al.* (1999) also reported significant effect of period on culling and found that involuntary culling had an ascending trend over different periods, whereas, voluntary culling had a descending trend. Similarly, there was significant effect of period of first calving on disposal of Sahiwal cows upto 4 lactations (Upadhyay *et al.* 2014).

Logistic regression analysis, carried out to examine the effect of non-genetic factors viz. CT, NLC, SC and PC on culling of Karan Fries cows indicated that these factors had a significant effect on culling during earlier parities and the effect of these factors was not significant in case of culling of older cows. Though the conventional model fitness criterion had lower estimates; however, ROC curve analysis confirmed the role of these environmental factors in prediction of culling increased with higher parities. Overall, the logistic regression was efficient in predicting the disposal of Karan Fries cattle.

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