International Journal of Livestock Production

Volume 6 Number 2 February 2015
ISSN 2141-2448

Academic Journals

ABOUT IJLP

The **International Journal of Livestock Production (IJLP)** is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Selective breeding in animal husbandry, the health effects of animal cruelty, fishery in terms of ecosystem health, Fisheries acoustics etc.
The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in the IJLP are peer-reviewed.

International Journal of Livestock Production (IJLP) (ISSN 2141-2448) is monthly (one volume per year) by Academic Journals.

Contact Us

Editorial Office: ijlp@academicjournals.org

Help Desk: helpdesk@academicjournals.org

Website: http://www.academicjournals.org/journal/IJLP

Submit manuscript online http://ms.academicjournals.me/

Editors

Editorial Board

International Journal of Livestock Production

Table of Contents: Volume 6 Number 2 February 2015

ARTICLES

Research Articles

academicJournals

Vol. 6(2), pp 16-25, February 2015
DOI: 10.5897/IJLP2014.0239
Article Number: 58EC6BF50726
ISSN 2141-2448

http://www.academicjournals.org/IJLP

International Journal of Livestock Production

Full Length Research Paper

Milk composition of Chiapas sheep breed under grazing conditions

Karin Nicole Carrillo-Pineda[1], Reyes López-Ordaz[2], Adimelda del Carmen Méndez-Gómez[3], Marisela Peralta-Lailson[3], Raúl Ulloa-Arvizu[1] and Carlos Gustavo Vázquez-Peláez[1]*

[1]Departamento de Genética y Bioestadística, Facultad de Medicina Veterinaria y Zootecnia, Universidad Nacional Autónoma de México. Av Universidad 3000, Ciudad Universitaria México 01710 D.F.
[2]Departamento de Producción Agrícola y Animal, Unidad Xochimilco, Universidad Autónoma Metropolitana, Calz del Hueso 1100, Coyoacán, Villa Quietud, 04960 Ciudad de México, D.F.
[3]Facultad de Medicina Veterinaria y Zootecnia, Universidad Autónoma de Chiapas. KM 8, carretera Teran, Ejido Emiliano Zapata, Tuxtla Gutierrez Chiapas, México.

Received 4 November, 2014; Accepted 12 January, 2015

The objective of this study was to estimate and model the percentage of protein, fat, lactose, non-fatty solids and protein-fat relationship variation in a 90-day milking period, from 136 test-day milk yield records of 46 Chiapas ewes. Least square means were estimated using a mixed model with repeated measures considering year (2006 to 2007), lactation (2, 3, 4, 5), variety (white, brown and black) and the interaction between lactation and variety. The relationship between days of lactation and daily milk yield (ml) and composition was modeled using random regression techniques. Least square means were 14.2 ± 0.36 kg for milk yield per lactation, 169.12 ± 4.97 ml/ewe/day, 5.49 ± 0.04% for protein, 4.37 ± 0.17% for fat, 4.53 ± 0.03% for lactose, 11.08 ± 0.04% for non-fat solids and 1.56 ± 0.07 for protein-fat relationship. Daily milk yield showed constant decreasing, while milk components presented quadratic trend during milking period. The component percentages of protein, fat, lactose, non-fatty solids and protein: fat relationship remained constant during the first five lactations and varieties showed similarity between milk composition studied traits, except in fat content, where the white variety had the highest proportion and the black variety the lowest, with a difference of 30%, whereas the brown variety was intermediate between these two. The results of the present study show the feasibility of selecting the Chiapas sheep breed for milk production and for a dual-purpose animal (wool-milk) under grazing conditions in the Altos de Chiapas, Mexico.

Key words: Protein in sheep milk, fat in sheep milk, lactose in sheep milk, Composition of sheep milk, Chiapas sheep breed, modeling milk composition, random regression.

INTRODUCTION

Sheep milk production worldwide has been used for consumption, cheese and yoghurt. Elaboration through local breeds with particular production standards has a direct relationship between milk composition and final products, such is the case of the Sarda breed for production of ricotta cheese; Lacaune, for Roquefort

*Corresponding author. E-mail: carlosgv@unam.mx. Tel: (+52) 5 556225894.

Table 1. Comparative composition of Fat (%), Protein (%), Lactose (%) and Solid non fat (%) in different sheep breeds.

Breed	Fat (%)	Protein (%)	Lactose %	NFS %	Comment	Reference
Several Breeds	7.62	6.21	3.7	10.33	Review	Jandal (1996)
Epirus mountain	7.85	6.56	4.77	12.13	Milking twice/d	Simos et al. (1996)
Sarda	10.5	5.5			1st lactatinon	Sanna et al. (1997)
Sarda	11.8	5.71			2nd lactation	Sanna et al. (1997)
Sarda	11.7	5.76			3th lactation	Sanna et al. (1997)
Sarda	11.5	5.79			4th lactation	Sanna et al. (1997)
Sarda	11	5.81			5th lactation	Sanna et al. (1997)
Chios	6.77	5.45	4.86	11.05		Ploumi et al. (1988)
Massese	6.24	5.75	4.92			Pugliese et al. (2000)
Sarda	6.69	5.99	4.74		Milking once/day	Nudda et al. (2002)
Sarda	6.44	5.41	4.88		Miliking twice/day	Nudda et al. (2002)
Awassi	7.48	5.58	4.79		Milking once/day	Nudda et al. (2002)
Awassi	6.86	5.15	4.88		Miliking twice/day	Nudda et al. (2002)
Merino	8.31	6.32	4.61		Milking once/day	Nudda et al. (2002)
Merino	7.67	5.66	4.86		Miliking twice/day	Nudda et al. (2002)
Rambouillet	5.6	5.2	4.5	16.7	Intensive conditions	Ochoa-Cordero et al. (2002)
Assaf and Awassi	4.68	5.13	5.3			Leitner et al. (2003)
Assaf and Awassi	5.29	5.5	4.72		Subclinical mastitis	Leitner et al. (2003)
Guirra	8.47	6.6	4.67	20.63		Jaramillo et al. (2008)
Manchega	9.3	6.59	4.48	21.24		Jaramillo et al. (2008)
Massese	6.41	5.77	4.5	11.12		Marrtini et al. (2008)
Lacces	7.84	5.4	4.62	18.84	LGB genotype AA	Dario et al. (2008)
Lacces	7.8	5.52	4.64	18.95	LGB genotype AB	Dario et al. (2008)
Lacces	7.48	5.3	4.58	18.34	LGB genotype BB	Dario et al. (2008)
Rage	4.68 - 11.8	5.13 - 6.6	3.7 - 5.3	10.33 - 21.24		
Chiapas Breed (Biotype: White)	4.92	5.52	4.52	11.06	Present study	Carrillo et al. (2014)
Chiapas Breed (Biotype: Brown)	4.12	5.41	4.61	11.01	Present study	Carrillo et al. (2014)
ChiapasBreed (Biotype: Black)	3.78	5.46	4.55	11.05	Present study	Carrillo et al. (2014)

cheese; Manchega, for manchego cheese; Latxa, for Idiazabal cheese; Saloia, for Nisa cheese, etc., (Scintu and Piredda, 2007). Composition in sheep milk has been widely studied (Table 1) and variation has been attributed to different effects such as breed, lactation, management, among others for protein (5.13 to 6.6%), fat (4.68 to 11.8%), lactose (3.7 to 5.3%) and non-fatty solids (10.33 to 21.24%). Protein percentage is two times higher than goat or cow (Jandal, 1996) and fat, protein, ashes, non-fatty solids and total solids are superior than goat, cow and human milk; lactose content however is superior to goat milk, but inferior to cow and human milk (Pandy and Ghodke, 2007). In the High land of Chiapas, Mexico, a production system prevails based on a local breed, defined as Chiapas sheep breed (Pedraza et al., 1992; FAO, 2009), with three colour phenotypes (white, brown and black), which have been maintained as a separate closed flock. Traditional management is done by the indigene of the region, mainly for wool production (Perezgrovas and Castro, 2000). Studies on milk yield show that the Chiapas sheep breed can be considered for milk and cheese production. Peralta et al. (2005), using nonlinear models and Vázquez et al. (2014), using different random regression models, characterized the lactation curve of this breed. Perezgrovas and Castro (2000), presented from a random sample of ewes of this breed has a range of 5.5 to 5.9% for protein, 5.8 to 5.9% for fat, 4.3 to 4.6% for lactose and 16.7 to 17% for non-fatty solids. Pedraza and Peralta (2003) mentioned that there is a relationship of 4:1 l/kg of produced cheese. Raynal-Ljutovac et al. (2008) mentioned that the effects of lactation status, season of the year, breed, genotype and nutrition are important factors to be considered in sheep milk production. Therefore, the objective of the present study was to model the variation in protein, fat, lactose, non-fatty solids and protein: fat relationship during lactation and other environmental effects in Chiapas sheep breed, using random regression techniques.

MATERIALS AND METHODS

A total of 136 test-day milk yield records of 46 ewes [white (13), brown (10) and black (23)] of Chiapas sheep breed were measured in two consecutive years (2006 and 2007). Because of the number of observations, parities 2, 3, 4 and 5 were considered where records of first and second parity animals were grouped as a class. Records were obtained in random days between ewes covering the total milking period, hand milking was performed in rustic facilities once a day and at every milking, milk yield was recorded.

Two samples of approximately 125 ml per ewe in each sampling were homogenized by agitation and fat, protein, lactose and non-fatty solid values were recorded, using specialized equipment.[1] Management and feed was described previously (López-Ordaz et al., 2012); briefly the study was conducted at the University Centre for Technology Transfer - Autonomous University of Chiapas, located in the Highlands (1780 masl) of Chiapas, Mexico. Ewes were free range grazing during the day on native grasses (*Pennisetum clandestinum*) and grain supplemented during the afternoon with free access to water. A mixed model with repeated measures (SAS, 2011) was used to estimate environmental effects on daily milk yield (ml), protein (%), fat (%), lactose (%), non-fatty solids (%) and protein: fat relationship, according to the following statistical model:

$$Y_{ijkno} = \mu + A_i + P_j + B_k + PxB_{jk} + animal_{n(jk)} + e_{ijkno}$$

Where: Y_{ijkno} was the value of each analyzed variable; μ was the general mean; A_i was the fixed effect of i-ith year of study (i = 2006, 2007); P_j was the fixed effect of j-ith class of parity number (j = 2, …, 5); B_k was the fixed effect of k-ith animal colour (k = white, brown, black); PxB_{jk} was the fixed effect of the interaction of parity number and variety; $animal_{n(jk)}$ was the random effect of n-ith animal nested in j-ith parity number and k-ith variety of the ewe ~ niid $(0,\sigma_{\alpha}^2)$; and e_{ijkno} was the random error ~ niid $(0,\sigma_{e}^2)$. The animals were used as subject in the repeated-measures command of the model. Following a similar procedure as suggested by Littell et al. (2000), the statistical model was fitted specifying each of the following structures of covariance: compound symmetry (CS), compound symmetry with heterogeneous variances (CSH), autoregressive type 1 [AR(1)], autoregressive type 1 with heterogeneous variances [ARH(1)], Toeplitz (TOEP), Toeplitz with heterogeneous variances (TOEPH) and unstructured (UN).

The goodness-of-fit of the models with different structures of specific covariance was compared using the Akaike information criterion (AIC), minus two times the restricted log likelihood function (-2 LogResL), and the Bayesian information criterion (BIC) using the MIXED procedure (SAS, 2011). The covariance structure that yielded the lowest value was considered as the one generating best fit in analyzed data.

A univariate model was used for analyzing the characteristics of: milk yield, protein, fat, lactose and non-fatty solids, using a model with both fixed effects and linear regression random effects for analyzing the test-day production records in Chiapas sheep breed. The relationship between DIM and DMY (ml), P (%), F (%), L (%), NFS (%) and P:F relationship were determined using n-th degree Legendre polynomial of the best model found with random regression (SAS, 2011).

The animal within the variety was considered as experimental unit in the random command of the analysis of variance and the first three order Legendre polynomials were fitted for each analyzed characteristic. Modeling was suspended when the parameter of the new term in the random regression model did not show statistical significance (P > 0.05). For each variable, the best model was selected comparing the restricted maximum likelihood (Mc Ardle, 2012). -Log likelihood function [log(L)] = 2log(ML_k); Akaike information criterion (AIC) AIC_k = -2log(ML_k) + 2p_k (Akaike, 1973) and Bayesian information criterion (BIC): BIC_k = -2log(ML_k) + p_k log(n) (Littell et al., 2006). The random regression model was represented as:

$$y_{km} = \sum_{i=0}^{a} b_i P(x)_k^i + \sum_{i=0}^{b} \alpha_{im} P(x)_m^i + e_m$$

Where: y_{km} was the k-th observation of the variable studied at lactation day when the measurement of the m-th animal was made; b_i were fixed regression coefficients for day in milk function (b_0 = intercept, b_1 = linear effect, b_2 = squared effect and b_3 = cubic effect); α_{im} was the i-th random regression coefficient; (α_{0m} = intercept, α_{1m}= linear effect, α_{2m}= squared effect, y α_{3m} = cubic effect) of the milk production curve of the variable studied per day of lactation belonging to m-th animal (m = 1,…,54); x_{kml}^{i} is the k-th observation of the standardized lactation, at the moment of sampling m-th animal, raised to the power 0, 1, 2 and 3; e_{km} was the error associated with observation y_{km}. The standardized unit of time (x) was lactation day ranging from -1 to +1 and was calculated using the expression:

$$x = 2\left(\frac{t - t_{min}}{t_{max} - t_{min}}\right) - 1$$

Where: *x* represnt the standarized unit of time from -1 to 1; *t* was day in milk at the moment of sampling; t_{min} was the earliest day in milk (9 in this study) and t_{max} the latest day of recorded sample (83 in this study). According to Kirkpatrick et al. (1990), the first three Legendre polynomials for the standardized time (x) are:

$$P(x)^0 = 1;\ P(x)^1 = x;\ P(x)^2 = \tfrac{1}{2}(3x^2 - 1);\ P(x)^3 = \tfrac{1}{2}(5x^3 - 3x)$$

The fit of the random regression models was carried out following a procedure similar to that suggested by Burnham and Anderson (2004). The restricted maximum likelihood method was specified in the command of the MIXED procedure model. Different order combinations of Legendre polynomials were analyzed to fit the best model and -2 Res Log Likelihood was used as comparison criterion.

[1] Milko Scope, July 4

Table 2. Comparison criteria with compound symmetry for first and second order Legendre polynomials for daily milk yield, protein %, fat %, lactose, non-fatty solids % content in milk and protein: fat relationship in Chiapas sheep breed in 83 days of lactation.

Parameter		Likelihood criteria[a]					
		-2 Res Log Likelihood	AIC	AICC	BIC	Variance	Residual
Milk yield	Legendre 1	1.7	7.7	7.9	13.6	2319.67	886.23
	Legendre 2	0	6	6.2	11.9	1903.22	831.82
Protein (%)	Legendre 1	36.5	42.5	42.7	48.4	0.2503	0.03933
	Legendre 2	0	6	6.2	11.9	0.08142	0.01701
Fat (%)	Legendre 1	0	6	6.2	12	0.5999	0.7605
	Legendre 2	3.1	9.1	9.3	15	1.9126	0.3484
Lactose (%)	Legendre 1	5.2	11.2	11.4	17.1	0.2024	0.01303
	Legendre 2	0	6	6.2	11.9	0.09342	0.00524
NFS (%)	Legendre 1	10.5	16.5	16.7	22.4	0.07966	0.05463
	Legendre 2	0	6	6.1	11.9	0.0953	0.01218
P:F	Legendre 1	54.8	60.8	61	66.7	0.5749	0.2572
	Legendre 2	0	6	6.2	11.9	0.5867	0.06564

[a] Expressed as difference of the lower.

RESULTS AND DISCUSSION

Table 2 shows the likelihood criteria for the comparison of the models, where the best fit consisted of a second order polynomial in the fixed part of random regression and a random intercept for protein (%), fat (%), lactose (%), non-fatty solids (%) and protein: fat relationship and linear for daily milk yield (ml).

Least square means for the environmental effects over the milking period are presented in Table 3. These values are within the ranges presented by Ochoa-Cordero et al. (2002), who in their review presented the average of 20 breeds between 1979 and 2002, with milk composition ranging from 3.4 to 6.5 for protein (%), 5.1 to 12.6 for fat (%), 4.4 to 5.5 for lactose (%) and 14.5 a 23.4 % for non-fatty solids. Parity effect showed lower milk production on average per day (29%) on ewes from second parity with regard to older ones ($P \leq 0.09$), there was no significant effect ($P \geq 0.22$) of parity number on milk composition traits.

The breed variety effect showed significant effect ($P \leq 0.02$) on fat (%), where the white ewes was 30% more than the black variety; while the brown variety showed to be intermediate, although the difference with the white variety was smaller than with the black variety. Protein was not statistical different ($P \geq 0.65$) among the three varieties, protein: fat relationship was greater in the black variety with regard to the other two ($P \leq 0.10$). The interaction of parity number between varieties for lactose percentage ($P \leq 0.01$) was found, where the brown variety showed 3% more in the second lambing with respect to the other two varieties in the same lambing, being similar in subsequent parities.

Previous studies on this breed showed that the brown variety has greater milk yield per lactation/day (Perezgrovas and Castro, 2000; Peralta et al., 2005). In the present study, there were no statistical differences in yield between varierities, although the same behavior and lack of significance can be attributed to the reduced number of observations.

Traditionally, the production of hard or semi-hard cheese is based on fat, protein and lactose content. The values found in Chiapas breed show that protein, fat and lactose are within the range presented by Raynal-Ljutovac et al. (2008), while the non-fat solid content is 3% below the inferior limit. Milk protein and lactose content for breed varieties are similar to the previous report (Perezgrovas and Castro, 2000), while fat and non-fat solid content were lower in all varieties; these differences can be because of the results presented by Perezgrovas and Castro (2000), the evaluation was carried out in only one sample, while in this study, the average was obtained across different phases of lactation.

Table 4 shows the phenotypic correlations between traits. In general, the direction of the correlations, although with different magnitude in Chiapas breed was similar to those shown in literature (Simos et al., 1996, in Mountain Epirus ewes; Sanna et al., 1997, in Sarda ewes; Ochoa-Cordero et al., 2002, in Rambouillet ewes). The difference in magnitude can be explained by differences between breeds and environmental factors,

Table 3. Least square means and standard error for milk yield characteristics per lactation (total PL) (kg); daily milk yield (milk/day) (ml/ewe); protein (%), fat (%), lactose (%), non-fatty solids (%) and protein: fat relationship in Chiapas sheep breed with respect to year, parity number, biotype and interaction between parity number and biotype in 83 days of lactation.

Effect	Total PL	Milk/day	Fat %	Protein %	Lactose %	NFS %	P : F
Year	**P = 0.43**	**P = 0.72**	**P = 0.09**	**P = 0.17**	**P < 0.0001**	**P < 0.0001**	**P = 0.55**
2006	13.2 (1.02)	169.96 (12.2)	3.83 (0.33)	5.38 (0.08)	4.84 (0.04)a	11.32 (0.10)a	1.68 (0.17)
2007	14.2 (0.88)	162.96 (12.3)	4.72 (0.32)	5.54 (0.07)	4.28 (0.04)b	10.76 (0.09)b	1.52 (0.16)
Parity (P)	**P = 0.23**	**P = 0.09**	**P = 0.68**	**P = 0.53**	**P = 0.22**	**P = 0.73**	**P = 0.93**
2	11.0 (1.65)	128.1 (21.3)[a]	3.76 (0.52)	5.32 (0.12)	4.67 (0.06)	11.03 (0.16)	1.69 (0.26)
3	14.9 (0.91)	187.4 (12.1)[b]	4.34 (0.30)	5.47 (0.07)	4.51 (0.04)	11.04 (0.09)	1.51 (0.15)
4	14.8 (1.24)	170.7 (16.7)[b]	4.62 (0.38)	5.55 (0.09)	4.53 (0.05)	11.14 (0.12)	1.61 (0.20)
5	14.1 (1.63)	179.7 (21.4)[b]	4.37 (0.52)	5.51 (0.12)	4.53 (0.07)	10.95 (0.16)	1.58 (0.27)
Biotype (B)	**P = 0.63**	**P = 0.7**	**P = 0.02**	**P = 0.65**	**P = 0.41**	**P = 0.96**	**P = 0.10**
White	13.4 (1.33)	160.2 (15.95)	4.92 (0.32)a	5.52 (0.07)	4.52 (0.04)	11.06 (0.11)	1.34 (0.17)
Brown	14.7 (1.52)	178.82 (19.58)	4.12 (0.45)ab	5.41 (0.10)	4.61 (0.06)	11.01 (0.14)	1.66 (0.23)
Black	13.0 (0.86)	160.36 (10.83)	3.78 (0.24)b	5.46 (0.05)	4.55 (0.03)	11.05 (0.08)	1.8 (0.12)
P x B	**P = 0.43**	**P = 0.53**	**P = 0.50**	**P = 0.23**	**P = 0.01**	**P = 0.14**	**P = 0.44**
2 white	12.3 (1.59)	141.21 (21.69)	4.68 (0.51)	5.59 (0.12)	4.48 (0.06)	11.15 (0.16)	1.35 (0.26)
2 brown	7.7 (4.1)	94.00 (51.63)	2.71 (1.28)	5.12 (0.29)	5.00 (0.15)	11.07 (0.38)	2.2 (0.63)
2 black	12.9 (1.36)	149.19 (18.41)	3.89 (0.44)	5.26 (0.10)	4.55 (0.05)	10.88 (0.13)	1.52 (0.22)
3 white	13.7 (1.29)	183.15 (19.19)	4.95 (0.51)	5.62 (0.12)	4.57 (0.06)	11.25 (0.15)	1.46 (0.26)
3 brown	17.5 (2.04)	204.33 (24.98)	4.34 (0.55)	5.41 (0.13)	4.39 (0.07)	10.89 (0.18)	1.34 (0.28)
3 black	13.4 (1.11)	174.58 (15.85)	3.73 (0.40)	5.39 (0.09)	4.57 (0.05)	10.96 (0.12)	1.74 (0.20)
4 white	14.8 (1.91)	164.94 (26.17)	5.6 (0.57)	5.57 (0.13)	4.6 (0.07)	11.28 (0.19)	1.29 (0.30)
4 brown	15.5 (1.84)	172.6 (22.83)	4.97 (0.52)	5.6 (0.12)	4.51 (0.07)	11.2 (0.16)	1.31 (0.26)
4 black	14.1 (1.64)	174.48 (24.97)	3.29 (0.62)	5.46 (0.14)	4.47 (0.08)	10.95 (0.19)	2.22 (0.32)
5 white	12.8 (4.06)	151.5 (49.25)	4.46 (1.03)	5.31 (0.24)	4.42 (0.13)	10.57 (0.35)	1.24 (0.54)
5 brown	18.0 (2.63)	244.35 (41.48)	4.46 (1.06)	5.51 (0.25)	4.55 (0.14)	10.88 (0.32)	1.78 (0.55)
5 black	11.6 (1.91)	143.19 (24.47)	4.2 (0.59)	5.72 (0.13)	4.62 (0.07)	11.4 (0.18)	1.72 (0.30)
Residual		1440.82	3.39	0.15	0.03	0.12	0.66
Mean	14.2 (0.36)	169.12 (4.97)	4.37 (0.17)	5.49 (0.04)	4.53 (0.03)	11.08 (0.04)	1.56 (0.07)

a, b different letters within the effect are statistically different.

such as production system and nutrition. The estimates of fixed and random regression for daily milk yield, protein (%), fat (%), lactose (%), non-fat solids (%) and protein: fat relationship are shown in Table 5. The scatter plot and the fixed model are shown in Figure 1 and random regression of variety is shown in Figure 2. The best model for daily milk yield was of first order Legendre polynomials, while for protein (%), fat (%), lactose

Table 4. Phenotypic correlations for daily milk yield (ml/ewe), protein (%), fat (%), lactose (%), non-fatty solids (%) and protein: fat relationship in Chiapas sheep breed in 83 days of lactation.

Characteristic	Protein%	Fat %	Lactose%	NFS %	Protein:Fat
Milk/day	-0.19*	-0.12	-0.26**	-0.41**	0.07
Protein (%)		0.45**	-0.34**	0.55**	-0.21*
Fat (%)			-0.39**	0.004	-0.82**
Lactose (%)				0.56**	0.22*
NFS (%)					0.04

* P < 0.05, **P < 0.01.

Table 5. Least square means of polynomial regression coefficients for daily milk yield, protein (%), fat (%), lactose (%), non-fatty solids (%) and protein: fat relationship and by biotypes (white, brown, black).

Parameter		Random regression estimates		
		α_0	α_1	α_2
Milk yield		**170.76 (7.20)*** **	**-33.962 (5.26)*** **	
	White	174.54 (10.55)	-42.10 (5.29)	
	Brown	175.57 (12.72)	-30.11 (6.38)	
	Black	166.40 (8.28)	-30.58 (4.15)	
Protein (%)		**5.45 (0.04)*** **	**0.19 (0.04)*** **	**0.33 (0.06)*** **
	White	5.52 (0.07)	0.15 (0.04)	0.20 (0.07)
	Brown	5.52 (0.08)	0.11 (0.05)	0.12 (0.09)
	Black	5.37 (0.05)	0.27 (0.03)	0.43 (0.06)
Fat (%)		**4.11 (0.19)*** **	**2.45 (0.21)*** **	**-0.42 (0.24)[a]**
	White	4.67 (0.28)	2.65 (0.20)	-0.61 (0.22)
	Brown	4.78 (0.34)	2.65 (0.24)	-0.80 (0.26)
	Black	3.49 (0.22)	2.25 (0.15)	-0.14 (0.17)
Lactose (%)		**4.54 (0.04)*** **	**0.041 (0.03)b**	**-0.17 (0.04)** **
	White	4.50 (0.07)	0.05 (0.03)	-0.19 (0.05)
	Brown	4.39 (0.09)	0.05 (0.04)	-0.09 (0.06)
	Black	4.62 (0.06)	0.03 (0.03)	-0.19 (0.04)
NFS (%)		**11.06 (0.06)*** **	**0.21 (0.06)** **	**0.16 (0.07)** **
	White	11.12 (0.10)	0.20 (0.08)	0.11 (0.07)
	Brown	10.94 (0.12)	0.13 (0.09)	0.08 (0.09)
	Black	11.08 (0.08)	0.25 (0.06)	0.23 (0.06)
P:F relationship		**1.67 (0.09)*** **	**-0.94 (0.15)*** **	**0.43 (0.13)** **
	White	1.55 (0.12)	-0.96 (0.15)	0.60 (0.13)
	Brown	1.41 (0.14)	-0.80 (0.18)	0.54 (0.15)
	Black	1.84 (0.09)	-0.99 (0.12)	0.27 (0.10)

a P < 0.09, b P < 0.16, * P < 0.05, ** P < 0.01 and *** P < 0.0001.

(%), non-fat solids (%) and protein: fat relationship, the best fit model consisted in a second order polynomial.

In a previous study, Vázquez et al. (2014) observed third order Legendre polynomials for lactation curve with daily milk measurements in 120 days period of time in this same breed, with values of: 115.67 (2.46), -49.34 (1.58), 4.61 (1.6) and -6.57 (1.43) for estimates of α_0, α_1, α_2 y α_3, respectively, for which the difference can be explained due to the sampling number between both studies, being the estimates of α_1 with the same trend in both studies.

The results of the present study, show that Chiapas sheep breed presents higher percentage of fat and protein than those reported by Jandal (1996) in goat and

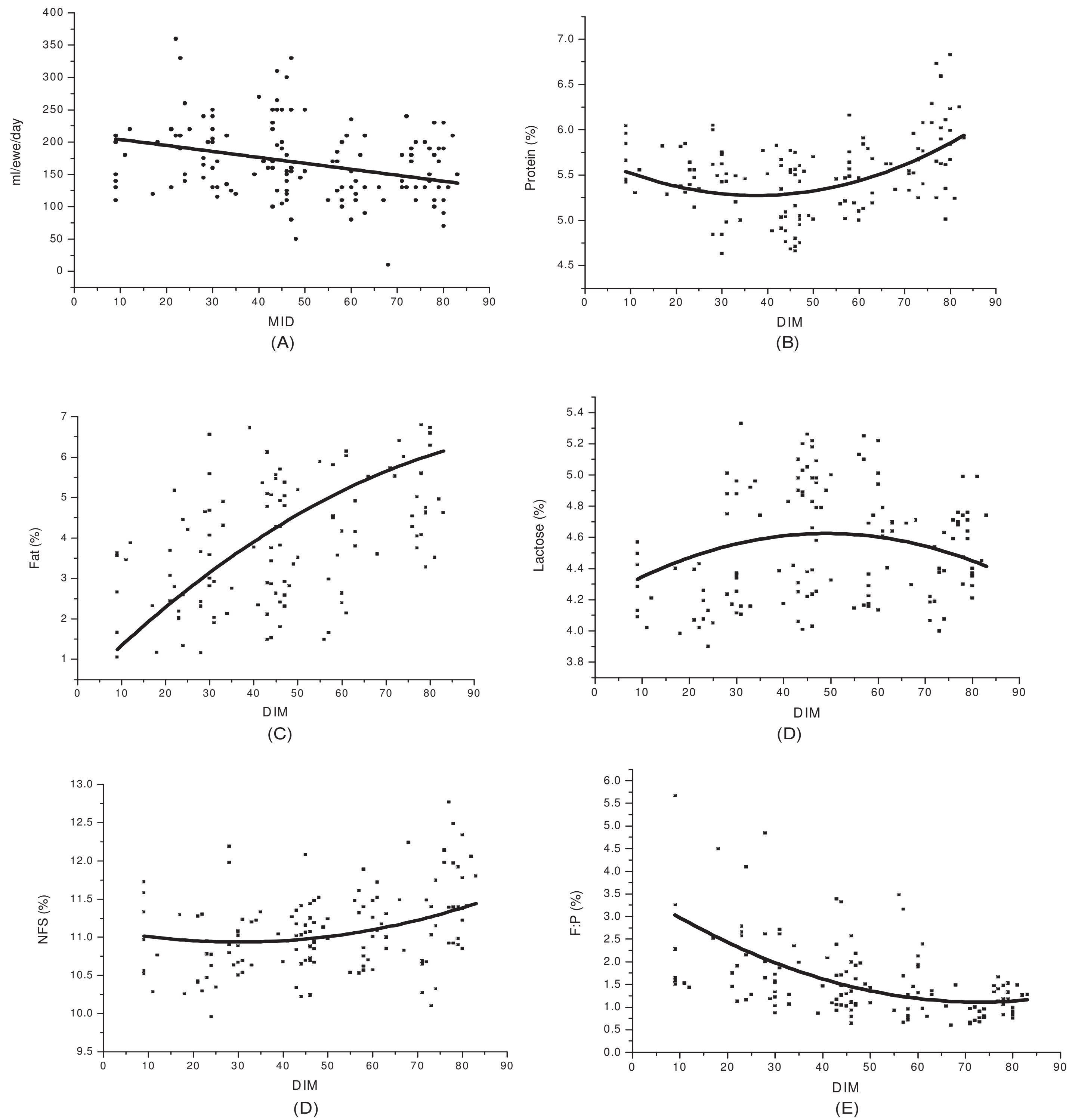

Figure 1. Scatter plot and fixed regression according to best fit Legendre polynomial for daily milk yield (A), protein % (B), fat % (C), lactose % (D), non-fatty solids % (E) and protein: fat relationship (F).

cow milk, but lower than in sheep milk, while lactose percentage being higher in goat and sheep milk and lower in cow milk. Finally, non-fat solids percentage is higher in goat, sheep and cow milk than in Chiapas breed ewes for the current work.

By their origin, ewe varieties (white, brown, black) from the Chiapas sheep breed are descendants of the Spanish breeds Churra, Lacha and Manchega, respectively;

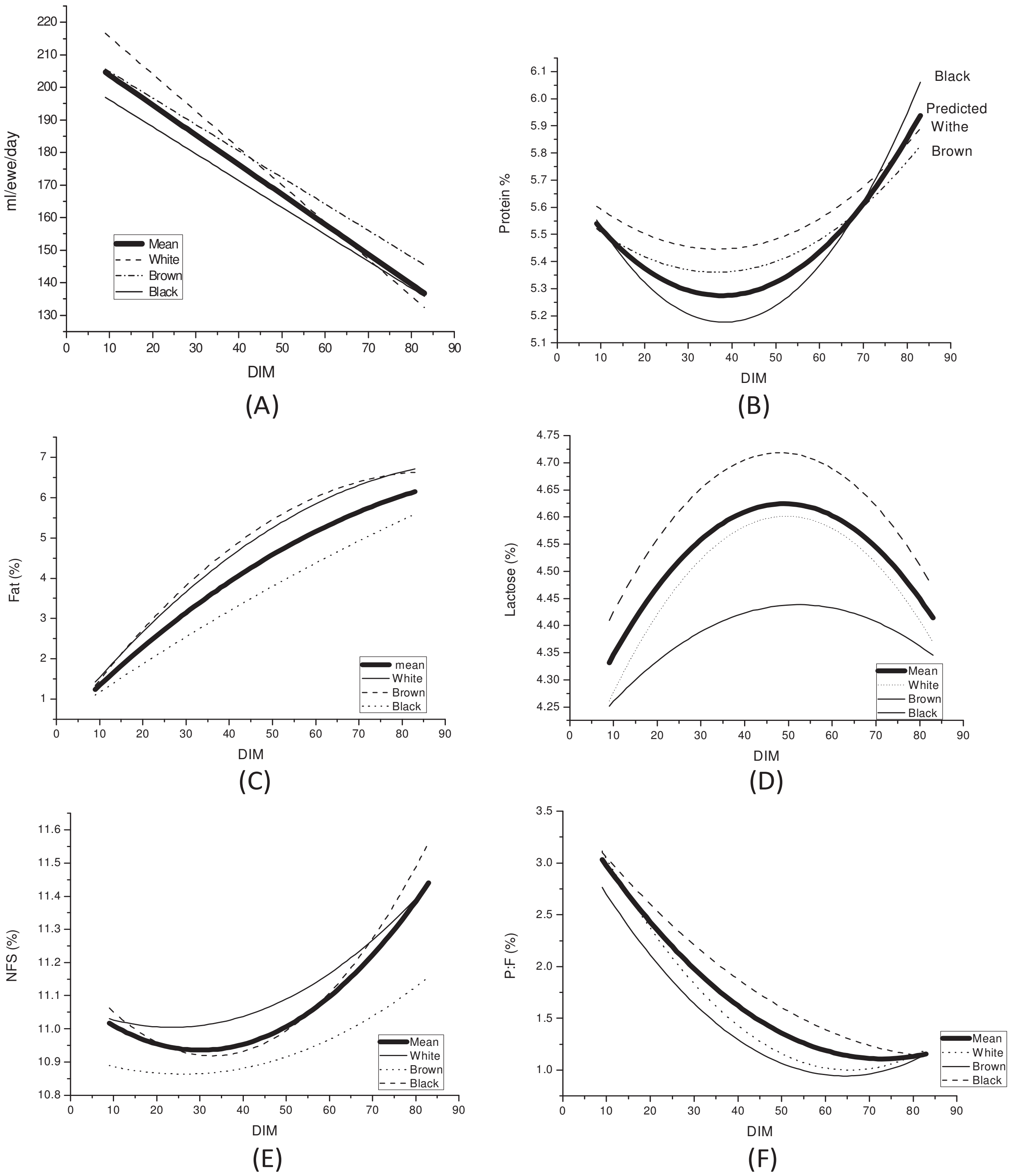

Figure 2. Mean regression of fixed model (continuous line) and random of biotype (dotted lines) for daily milk yield (ml/ewe/day) (A); protein (%) (B); fat (%) (C); lactose (%) (D); non-fatty solids (%) (E) and protein: fat relationship, mean (thick line) and by biotype (white, brown, black) in 90 days of lactation in Chiapas sheep breed.

however, it has been considered many years ago that Spanish breeds were selected for milk production. Churra breed is superior to the white variety of Chiapas breed in fat %, lactose (%) and non-fatty solids (%) and lower in protein (%) (Ochoa-Cordero et al., 2002). Lacha breed is 1.6 percentage points higher in fat (%) and similar in protein (%), with respect to the brown variety of Chiapas breed. Whereas, Manchega breed is 3.3 and 6.6% points higher than the black variety in fat (%) and non-fat solids (%) and similar in protein (%) and latose (%), in accordance with Ochoa-Cordero et al. (2002).

The quadratic behavior trend for protein, lactose and non-fat solids in the Chiapas sheep breed are similar to those presented by Simos et al. (1996), in Mountain Epirus ewes and Ochoa-Cordero et al. (2002), in Rambouillet ewes. On the other hand, fat (%) showed similar trend to Rambouillet ewes, but different to Epirus ewes, because this breed decreased to the 4^{th} month and increased in the 5^{th} and 6^{th} month and decreased again in the 7^{th} month.

Conclusion

Component percentages of protein, fat, lactose, non-fat solids and protein: fat relationship remained constant during the first five lactations. Chiapas sheep breed varieties showed similarity between milk composition characteristics, except in fat content (%), where the white variety had the highest proportion and the black variety the lowest, with a difference of 30%, whereas the brown variety was intermediate between these two. The results of the present study show the feasibility of selecting the Chiapas sheep breed for milk production and for dual-purpose animal (wool-milk) under natural conditions in the Altos de Chiapas, Mexico.

Conflict of Interest

The authors have not declared any conflict of interest.

ACKNOWLEDGEMENTS

Partial information of this study was used as a dissertation project by the first author for her Veterinary Medicine and Husbandry licensing process in the FMVZ-UNAM. Special thanks for financial support of projects UNAM-PAPIIT IN207707-3, UNAM-PAPIIT IN205710-3 and SAGARPA-CONACYT 2004-CO1-111/A1 and to the collaboration between the Facultad de Medicina Veterinaria y Zootecnia of the Universidad Nacional Autónoma de México and the Centro Universitario de Investigación y Transferencia de Tecnología of the Universidad Autónoma de Chiapas.

REFERENCES

Akaike H (1973). Information theory as an extensión of the máximum likelihood principle. In Petrov BN, Caski F (Eds.) Second international symposium on information theory. Akademiai Kiado, Budapest, pp 267-281.

Burnham KP, Anderson DR (2004). Multimodel inference understanding AIC and BIC in model selection. Soc Methods Res. 33: 261-304. doi.org/10.1177/0049124104268644

Dario C, Carnicella D, Dario M, Bufano G (2008). Genetic polymorphism of β-lactoglobulin gene and effect on milk composition in Leccese sheep. Small Rumin. Res. 74: 270-273. doi:10.1016/j.smallrumres.2007.06.007

FAO (2009). www.fao.org http://faostat.fao.org/site/569/DesktopDefault.aspx?PageID=669#ancor (October 2014).

Jandal JM (1996). Comparative aspects of goat and sheep milk. Small Rumin. Res. 22:177-185. doi:10.1016/S0921-4488(96)00880-2

Jaramillo DP, Zamora A, Guamis B, Rodríguez M, Trujillo AJ (2008). Cheesemaking aptitude of two Spanish dairy ewe breed: Changes during lactation and relationship between physicochemical and technological properties. Small Rumin. Res. 78: 48-55. doi:10.1016/j.smallrumres.2008.04.005

Kirkpatrick M, Lofsvold D, Bulmer M (1990). Analysis of the Inheritance, Selection and Evolution for Growth Trajectories. Genetics 124: 979-993.

Leitner G, Chaffer M, Caraso Y, Ezra E, Kababea D, Winkler M, Glickman A, Saran A (2003). Udder infection and milk somatic cell count, NAGase activity and milk composition – fat, protein and lactose – in israeli-Assaf an Awassi sheep. Small Rumin. Res. 49: 157-164. doi:10.1016/S0921-4488(03)00079-8

Littell RC, Milliken GA, Stroup WW, Wolfinger RD, Schabenberber O (2006). SAS© for mix models. Second Edition. Cary, NC: SAS Institute Inc, pp. 159-202

Littell RC, Pendergast J, Natarajan R (2000). Modeling covariance structure in the analisys of repeated measures data. Stat. Med. 19(13): 1793-1819.

López-Ordaz R, Olivera-Vega I, Berruecos-Villalobos JM, Peralta-Lyson M, Ulloa-Arvizu R, Vásquez-Peláez C (2012). Genetic parameters for birth and weaning weights in the local Chiapas sheep breed from Mexico. Rev. Mex. Cienc. Pecu. 3: 113-123.

Marrtini M, Scolozzi C, Cecchi F, Mele M, Salari F (2008). Relationship between morphometric characteristics of milk fat globules and the cheese making aptitude of sheep's milk. Small Rumin. Res. 74. 194-201. doi:10.1016/j.smallrumres.2007.07.001

Mc Ardle JJ (2012). Latent curve modeling of longitudinal growth data. in: Hoyle, R.H. (Ed.), Handbook of structural equation modeling. The Guilford Press, New York, pp. 547-571.

Nudda R, Bencici R, Mijatovic S, Pulina G (2002). The yield and composition of milk in Sarda, Awassi and Merino sheep milked unilaterally at different frequencies. J. Dairy Sci. 85: 2879-2884. doi:10.3168/jds.S0022-0302(02)74375-0

Ochoa-Cordero MA, Torres-Hernández AE, Ochoa-Alfaro AE, Vega-Roque L, Mandeville PB (2002). Milk yield and composition of Rambouillet ewes under intensive management. Small Rumin. Res. 43. 269-274. doi:10.1016/S0921-4488(02)00019-6

Pedraza P, Peralta M, Perezgrovas-Garza R (1992). El borrego Chipas: una raza local mexicana de origen español. Arch. Zootec. 41: 355-362.

Pedraza VP, Peralta LM (2003). Elaboración de queso de oveja bajo un sistema artisanal. In: Memorias XII Congreso Nacional de Producción Ovina. Asociación Mexicana de Técnicos Especialistas de Ovinocultura. Tulancingo Hidalgo, México, pp 115-120.

Peralta-Lailson M, Trejo-González AA, Pedraza-Villagómez P, Berruecos-Villalobos J M, Vásquez CG (2005). Factors affecting milk yield and lactation curve fitting in the creole-sheep of Chiapas-México. Small Rumin. Res. 58: 265-273. doi:10.1016/j.smallrumres.2004.11.005

Perezgrovas G, Castro GH (2000). El borrego Chiapas y el sistema tradicional de manejo de ovinos entre las pastoras tzotziles. Arch. de Zootec. México. 49: 391-403.

Ploumi K, Belibasaki S, Triantaphyllidis G (1998). Some factors affecting daily milk yield and composition in a flock of Chios ewes. Small Rumin. Res. 28: 89-92. doi:10.1016/S0921-4488(97)00077-1

Pugliese C, Acciaioli A, Rapaccini S, Parisi G, Franci O (2000). Evolution of chemical composition, somatic cell count and renneting properties of the milk of Massese ewes. Small Rumin. Res. 35. 71-80. doi:10.1016/S0921-4488(99)00070-X

Raynal-Ljutovac K., Lagriffoul G, Paccard P, Guillet I, Chillard Y (2008).

Composition of goat and sheep milk products: An update. Small Rumin. Res. 79 57-72. doi:10.1016/j.smallrumres.2008.07.009
Sanna SR, Carta A, Casu S (1997). (Co) variance component estimates for milk composition traits in sarda dairy sheep using a bivariate animal model. Small Rumin. Res. 25. 77-82. doi:10.1016/S0921-4488(96)00949-2
SAS (2011). Institute Inc., Cary, NC, USA
Scintu MF, Piredda G (2007). Typicity and biodiversity of goat and sheep milk products. Small Rumin. Res. 68 221-231. doi:10.1016/j.smallrumres.2006.09.005
Simos EN, Nikolau EM, Zoiopoulos PE (1996). Yield, composition and certain physicochemical characteristiscs of milk of the Epirus Mountain sheep breed. Small Rumin. Res. 20: 67-74. doi:10.1016/0921-4488(95)00780-6
Vázquez-Peláez CG, García-Muñiz JG, Lopez- Villalobos N (2014). Empirical models used for lactation curve analysis in the Chiapas sheep breed using randon regresión models. Int. J. Livest. Prod. 5(3): 55-64. doi: 10.5897/IJLP2013.0177

academicJournals

Vol. 6(2), pp 26-34, February 2015
DOI: 10.5897/IJLP2014.0235
Article Number: 6C23E5C50734
ISSN 2141-2448

http://www.academicjournals.org/IJLP

International Journal of Livestock Production

Review

Developing a farm audit to address the problems of stock welfare on small holder dairy farms in Asia

J. B. Moran

Profitable Dairy Systems, 24 Wilson St. Kyabram, Victoria 3620 Australia.

Received 23 October, 2014; Accepted 4 February, 2015

The welfare of an animal relates primarily to its ability to cope, firstly with its external environment, such as housing, handing by humans, weather and the presence of other animals, and secondly with its internal environment, such as specific injuries or illnesses and nutritional status. Direct animal measurements are good indicators of animals' current well-being and help identify longer term animal welfare problems. These should integrate long term consequences of past husbandry practices, be non-intrusive, and free from observer bias. Many welfare protocols are based on the five "basic freedoms" for good animal welfare, namely freedom from hunger and thirst, discomfort, pain, fear and distress and freedom to express normal behaviour. To be objective, welfare indicators need to be quantifiable and scientifically based. This review presents a list of key performance indicators of stock welfare specifically relevant to tropical small holder dairy farms. They can be separated into six different categories, such as nutrition, reproduction, disease, external appearance, environmental injury and behaviour. The review also presents a standard approach for estimating an animal welfare index well suited to the thousands of smallholder dairy farmers throughout tropical Asia.

Key words*:* Dairy cattle, welfare protocols, tropics, small holder welfare index.

INTRODUCTION

The welfare of an animal relates primarily to its ability to cope, both with its external environment, such as housing, handing by humans, weather and the presence of other animals, and with its internal environment, such as specific injuries or illnesses and nutritional status. Welfare refers not only to the internal and external environments of animals, but how they feel (Phillips, 2002). These feelings can be negative, including pain, fear and hunger, or they can be positive, including calmness and happiness.

The health and welfare of an animal is closely linked with the health status of an animal influencing its welfare, and its welfare influencing its health (von Keyserlingk et al., 2009). Cattle kept in poor or chronically stressful conditions are more susceptible to disease and reduction in the level of productivity. Cattle with illnesses and injuries, particularly chronic ones, can often be classified as having poor welfare. Production can also be included in this relationship, with healthy and happy cattle being more productive.

European Food Safety Authority (2009) state that long term genetic selection for high milk yield in dairy cows is a major factor contributing to poor welfare, in particular health problems such as lameness, mastitis, metabolic

*Corresponding author. E-mail: jbm95@hotmail.com. Tel: +61418379652.

instability and longevity. In other words, we breed cows to produce more and more milk at the expense of their welfare. This is particularly relevant to poorly resourced dairy farmers and those who do not fully understand the impact of these genetically selected high milk yields can have on the nutrient demands of cows. These nutritional deficits then infringe on their welfare making them more susceptible to metabolic and reproductive problems.

According to the World Organisation for Animal Health (OIE, 2013) an animal is in a good state of welfare if it is healthy, comfortable, well nourished, safe, able to express its innate behaviour and is not suffering from negative states such as pain, fear, and distress. While the welfare of an animal is a dynamic thing dependent on changes in its health and environment, some simple, fundamental features will guarantee good welfare. These are: good hygiene, having continuous access to clean water, stable social groups and the provision of preventive veterinary care. Good animal welfare then requires disease prevention and veterinary treatment, appropriate shelter, management, nutrition, humane handling, transport and eventually, humane slaughter.

While the above definitions are accepted internationally, what people interpret to be acceptable animal welfare can be influenced by many factors including personal values, religion, nationality, gender, previous experiences, age, socio-economic status, education etc. The author of this review has recently written a reference book on the key aspects of welfare of stock on smallholder dairy farms in tropical Asia (Moran and Doyle, 2015).

WHY ANIMAL WELFARE IS IMPORTANT

Not only is it important to understand what welfare is, but we also need to know why it is of importance. Animal welfare is fundamentally linked to animal health and production (Moberg, 2001). Both clinical and sub-clinical disease states will compromise the welfare of animals. For example, lameness causes a cow to feel pain and as a result, this will impact on her ability to feed, rest, move and cope with other illnesses and stressful situations that she experiences. Poor welfare can also have a negative impact on the health of a cow. Stressful situations, such as negative treatment by a stockperson or ongoing aggressive interactions with other animals in the herd, will result in physiological and behavioural changes in the animal that are aimed at helping it to deal with the stress. If the stressor is prolonged, becoming chronic, these physiological responses can impact upon the immunity of the cow, making her more susceptible to disease. Poor welfare is also linked to reduced productivity, inhibiting the capacity for the cow to reproduce, reducing milk yields and body condition. For example, illness can reduce feed intake and divert resources from production to fighting infection while cattle experiencing fear during handling will also have reduced milk yields. Public perceptions of farm animal welfare issues have the potential to markedly affect the security and sustainability of our livestock industries. Nationally and internationally, these societal pressures are playing increasingly significant roles in determining how animals are managed and products are marketed while scientific findings assist development of welfare assessment, practice and improvement.

WHO SHOULD BE RESPONSIBLE FOR STOCK WELFARE?

There is considerable public debate about who should ultimately be responsible for stock welfare. Many of the breeder stock purchased specifically for increasing herd sizes on tropical small holder dairy farms in Asia did not originate from these countries and are frequently imported from temperate, developed dairy industries with a high regard for animal welfare. Whether it is appropriate for such poorly adapted stock to be transported direct from developed farms in temperate regions to often subsistence small holder dairy (SHD) farms in the humid and dry tropics has been a subject of continual discussion such as Moran (2012). Once the decision has been made and the funds allocated, it should be purely a commercial decision between the purchasing and the selling countries. However the debate does not stop at this point. Under what stipulations and what responsibilities should the exporting country take for the welfare of such stock once they arrive within the importing country? Should animals born and bred in a country with often more stringent stock welfare philosophies and practices be exported to countries with often less sophisticated approaches to stock welfare?

In certain developed dairy industries, such as Australia, there is considerable discussion in recent years between the various dairy stakeholders and the general public about the legitimacy of this trade. In such countries, lobby groups are becoming quite vocal in their attempts to influence public accountability in stock welfare practices. They are gradually impacting on such practices in the more intensive animal industries, such as the gradual removal of sow crates in pig production and of battery cages in poultry production systems. Such lobby groups are said to mainly represent societies more extreme opinions in animal farming, such as those promoting vegetarian lifestyles in which animal farming has no part.

With regards cattle welfare in Australia, these groups have been successful in reflecting the opinions of the general public such that in 2011, a television documentary program led to the Federal government legislating a complete ban on exporting live cattle for slaughter to Indonesia for several weeks, which had ramifications on the beef cattle breeder industry for several years at least. For the industry to be recommenced on a more “acceptable” footing, a series of measures were introduced to pass the ultimate responsibility of the cattle welfare from the public (government) to the private (export agents) sector. To date (early 2015) this only covers the export of cattle for fattening and slaughter but is likely to be extended to the export of cattle (both dairy and beef) for breeding purposes.

The responsibility of ensuring acceptable stock welfare practices to slaughter cattle, which are slaughtered within a few weeks of arrival in the importing country, is relatively easy to monitor. However when breeder cattle are exported to developing countries, often with different societal standards of acceptable stock welfare practices, such a responsibility could be more difficult to monitor because of the nature of the dairy industries, with thousands of poorly resourced, smallholder farmers, and the length of time that such monitoring would have to take place during the life of such cattle (that is several years rather than several weeks).

This is an ongoing concern within Australia's beef and dairy cattle industries, because of the increasing size of these relatively new export industry sectors, which number up to one million beef steers per year for slaughter and 100,000 dairy and beef heifers per year for breeding purposes. The live breeder cattle export trade has become a "win win" situation for both the purchasers and the suppliers. Not only does it increase national herd sizes hence domestic milk production in the purchasing countries, it also provides an additional source of income for dairy farmers in the supplying countries. This was particularly relevant in Australia during the extensive 2008 to 2009 national drought as it provided additional cash flow for dairy farmers while they were suffering markedly reduced income streams. In the process of addressing societies' concerns about acceptable cattle welfare practices, new capacity building programs have been introduced within the importing countries. Furthermore, there is now extra vigilance by both public and private sectors particularly those agencies with high profiles in stock welfare, in the stock handling and herd management practices in these countries. This can only lead to improvements in animal welfare, for the better well-being of the dairy stock.

INDICATORS OF ANIMAL WELFARE

There are many different methods that can be used to measure an animal's welfare and a balance needs to be sought so that enough measures are taken, scientifically-based, and that the data can be collected in a timely manner. When choosing direct measures of welfare, several factors need to be considered. Indicators should integrate the long-term consequences of past husbandry practices. They should be non-intrusive so as to cause minimal disturbances to the animals' natural behaviour. They must be reasonably free of observer bias and should highlight welfare problems and identify failures in farm management that contributed to such problems. Welfare observations should then be centred on three aspects:

(1) Validity. What does this indicator tell us about the animal's welfare state?
(2) Repeatability. Do different observers always see the same problem?
(3) Feasibility. How easy is it to record this indicator?

Most approaches to welfare assessment are based on indicators of reduced welfare. Understandably this is because the greatest compromise to welfare lies with negative situations. However, it is worthwhile putting more emphasis on indicators of good welfare. Environmental control and positive social interactions would be considered the main components of good welfare. Social and non-social play in calves or social licking in adult cows are examples of positive social activities, and stock are only motivated to perform such behaviours once their primary needs are satisfied. Animal welfare research and assessment is moving in this direction and more objective indicators of positive welfare will be developed with time.

Traditionally farm animal welfare audits have focused on measurements of resources provided to the animal such as housing-related facilities, management practices and human-animal relationships. These are often difficult to quantify and may not necessarily result in improved standards of animal welfare, although they can indicate risks or reasons for the animal's welfare. More direct animal measurements such as behaviour and health would be better indicators of their current well-being and help identify longer term animal welfare problems.

THE FIVE BASIC FREEDOMS OF LIVESTOCK

The welfare requirements of cattle can best be summarised in the "five freedoms" (Farm Animal Welfare Council, 2009). These were originally developed by the UK government as a part of a report into farm animal welfare (Brambell, 1965) but are now applied to all animals under the care of humans. These five freedoms are as follows:

(1) Freedom from hunger and thirst, through ready access to fresh water and a diet to maintain full health and vigour.
(2) Freedom from discomfort, through provision of appropriate shelter and comfortable resting areas.
(3) Freedom from pain, by prevention and, when sick, rapid diagnosis and treatment.
(4) Freedom from fear and distress by ensuring conditions which avoid mental suffering
(5) Freedom to express normal behaviour by providing adequate space, proper facilities and the company of

other animals.

These five freedoms address both physical fitness and mental suffering and are best viewed as a practical, comprehensive checklist to assess the strengths and weaknesses of any husbandry system. There is a hierarchy of needs of cattle and the five freedoms should not be taken to imply that all animals should be free from exposure to any stress, ever. The aim is not to eliminate stress but to prevent suffering and progress towards improved welfare by providing for the animal's needs. Suffering occurs when animals fail or have difficulty in coping with stress. All dairy cattle management and housing systems should be designed, constructed, maintained and managed to assist with these "five freedoms".

KEY PERFORMANCE INDICATORS OF CATTLE WELFARE

Key Performance Indicators (KPI) can act as a guide to help farmers diagnose the strengths and weaknesses in their dairy enterprise. Expressed simply, KPIs are then diagnostic tools to help identify weaknesses adversely affecting farm performance. Farmers can use these indicators to identify areas of animal welfare weaknesses, and help to give them an idea of their performance in relation to other farms. Comparing between farms can be a useful way to affect a change in practice as farmers are more likely to try to improve their management practices if they can identify where they are, compared to others, in terms of welfare and productivity. There are a variety of KPIs available for small-holder dairy farmers that cover health, productivity and welfare, and many of these have been highlighted by Moran (2009).

The Welfare Quality (2009) project has listed 12 such KPIs that relate to animal welfare. This is specifically for the first four "basic freedoms of livestock", as the fifth freedom, to express natural behaviour, should be assured if all else is satisfied. These 12 KPIs are:

(1) Animals should not suffer from prolonged hunger
(2) Animals should not suffer from prolonged thirst
(3) Animals should be comfortable, especially within their lying areas
(4) Animals should be in a good thermal environment
(5) Animals should be able to move around freely
(6) Animals should not be physically injured
(7) Animals should be free of disease
(8) Animals should not suffer from pain induced by inappropriate management
(9) Animals should be allowed to express natural, non-harmful, social behaviours
(10) Animals should have the possibility of expressing other intuitively desirable natural behaviours such as exploration and play
(11) Good human-animal relationships are beneficial to the welfare of animals
(12) Animals should not experience negative emotions such as fear, distress, frustration or apathy.

Unfortunately they are without quantitative descriptors, making it difficult to ensure repeatability of measures if using this list alone.

Similarly to the Welfare Quality project, Webster (2005) presented a list of the "top ten" indicators of welfare of dairy cows developed by a team of veterinarians and animal production scientists in the United Kingdom, these being:

(1) Observing lameness
(2) Examining health records
(3) Observing disease
(4) Observing mastitis
(5) Observing general demeanour
(7) Scoring body condition
(8) Observing stockperson ship
(9) Observing lying behaviour
(10) Examining production records
(11) Observing skin lesions

QUANTIFIABLE WELFARE INDICATORS

To be objective, welfare indicators need to be quantifiable. The following is a comprehensive list of such indicators. This list has been selected to be specifically relevant to tropical small holder dairy farms and has been separated into six different categories. These include the nine of the cow signals as listed by (Hulsen, 2011) for which scoring systems have been described by Moran and Doyle (2015). This detailed list utilises farm records as well as direct observation to assess welfare of the herd.

Nutrition

(i) Prolonged hunger; body condition score; % of very lean cows and % very fat cows
(ii) Rumen score; % cows with deeply hollow rumens
(iii) Dung score; % cows with any coarse particles in their dung and a consistency of stiff balls like horse manure
(iv)Prolonged thirst; number of stock per drinker or per cm of drinking trough, water flow and cleanliness of drinkers; this is not relevant to tie stall systems.
(v) Milk fever; % incidence/year
(vi) Metabolic diseases; % incidence/year, (such as ketosis or hypomagnesaemia, but not milk fever, mastitis or lameness).

Reproduction

(i) Assisted calving; % cows calving/year
(ii) Conceptions to first service; % cows/year

Table 1. Warning and alarm thresholds in percentages for different disease symptoms

Symptom	Warning threshold	Alarm threshold
%Cows with nasal discharge	5	10
%Cows with discharge from the eyes	3	6
Average frequency of coughing per cow per 15 min	3	6
%Cows with hampered respiration	3	6
%Cows with diarrhoea	3	6
%Cows with discharge from the vulva	2	4
%Dystocia in 12 months	2.5	5
%Downer cows in 12 months	2.5	5
%Mortality in 12 months	2	4

(iii) Average days from first service to conception
(iv) Average age at first calving

Disease

(i) Locomotion score; % cows moderately to severely lame
(ii) Hoof score; % cows with severe hoof inflammation
(iii) Teat score; % cows with rough callous ring around the teat ends
(iv) Mastitis, clinical cases; %/year
(v) Mastitis, subclinical cases; %/year
(vi) Indicators of disease (Table 1); mean number of coughs per cow per day, % on farm mortality, % downer cows, % cows with nasal discharge, % cows with hampered respiration
(vii) Disease in calves; % calves with diarrhoea, % calves requiring veterinary attention
(viii) Pre-weaning mortality; % calves died prior to weaning
(ix) Sudden deaths/casualties; % per year
(x) Dull/obviously sick cows; % cows per year
(xi) Indicators of pain; methods and use of anaesthetics and analgesics for disbudding, dehorning and tail docking

External appearance

(i) Cow cleanliness score; % cows with excessively dirty lower hind legs, hindquarters or udders
(ii) Cows with hair loss in lower limbs; % cows per year.

Environmental injury

(i) Leg score; % cows with severe rotation of their feet
(ii) Cows with swollen hocks; % cows per year
(iii) Cows with ulcerated hocks; % cows per year
(iv) Cows with non-hock traumatic injuries; % cows
(v) Ease of movement in laneways; % cows slipping and falling.

Behaviour

(i) Resting behaviour; % cows lying partly or completely outside resting area
(ii) Social behaviour; number of head butts and displacements/cow/hour
(iii) Flight distance, measured by approaching cows at the feed trough from a distance of 2.5 m and measuring the distance between the hand and muzzle at the moment the animal withdraws; % of cows 0 to 10 cm, 10 to 50 cm, 50 to 100 cm and >100 cm
(iv) Idle cows; % cows standing but performing no activity, such as rumination
(v) Rumination; % cows standing or lying that are ruminating
(vi) Rising restriction; % cows showing severe difficulty in rising, or hitting fittings as they rise or seen to be "dog sitting"
(vii) Heat stress; % cows with respiration rates exceeding 70 or 100 breaths per min
(viii) Cow comfort index; % cows standing or lying in free stalls.

THRESHOLDS FOR INITIATING HERD HEALTH PLANS

Some diseases affect few animals in a herd while others can spread very easily between animals. Welfare Quality (2009) has documented the incidence of symptoms of disease in terms of warning and alarm thresholds. The alarm threshold is the minimum value for a decision to put a health plan in place on the farm while the warning threshold is half the alarm threshold. These are presented in Table 1.The following checklist has been taken from the Assure (2010) program. It uses several of the measures detailed above and focuses more closely on direct observations of individuals and the herd to assess welfare. The measures chosen for this checklist specifically allow comparison between farms with different management systems. They also allow for the assessment of welfare on an individual animal level, as well as assessing the entire herd. This type of checklist is essential when you wish to conduct a brief, yet objective evaluation of welfare, or when herd records are available. Further details on these measurements (with may include photographic standards) are provided by Moran and Doyle (2015).

Individual measures

(i) Mobility: observe cow on a hard non-slip surface. Monitor the cow for 6 to 10 uninterrupted strides, observing the cow from the side and the rear.
(ii) Body condition: visually assess the cow from behind and from the side, the tail, head and loin areas.
(iii) Hair-loss, lesions and swelling: visually assess specific regions on the animal from the side. Areas include the head, shoulders, neck, flank, side, udder, hindquarter, front leg, and hind leg to hock. Scoring ranges from no to slight skin damage to lesion or swelling.
(iv) Dirtiness: Visually assess the lower hind legs including the hock, the hindquarters and the udder for dirtiness. Scores are clean, dirty or very dirty.

Herd measures

(i) Mobility and lameness management: assess the management strategies of 3 or more lame cows, including any in a hospital pen
(ii) Lying comfort: assess the number of cows not lying correctly (partly or completely outside the cubicle)
(iii) Broken tails: record numbers of cows with bent, short, injured, and broken tails
(iv) Response to stock person: observe the response of the cattle to the stockperson as they approach and interact. Scored as sociable, indifferent or cautious.
(v) Cows needing further care: assess the whole herd and record any sick or injured cows that need further intervention.

Recorded measures

(i) Mobility and verifying self-assessment: verify the stockperson's ability to identify lame cows
(ii) Mastitis: check farm records for incidences
(iii) Heifer and cow survivability: check farm records.

DEVELOPING A SYSTEM FOR DAIRY COW WELFARE ASSESSMENT

To improve animal welfare, farmers need to be able to assess their development over time, and then respond accordingly. Rousing et al. (2000) provide such a protocol based on four information sources namely:

(i) System: With loose housing, the welfare indicators would include the dimensions, partitions and surfaces of cow stalls, their physical positioning within the housing system, the laneways and exercise areas, the collection area and layout of the milking area and the design and placement of the feeding and watering facilities.
(ii) Management: This is all based on ensuring the care required to create and sustain good stockpersonship and welfare in the herd. For example, there should be appropriate and efficient designs of shed equipment for proper handling and inspection routines while other indicators would include stocking density (for feeding, drinking and resting), quantity and quality of bedding material, the availability of calving and hospital pens, the method of feeding (feed quality and whether it is restrictive or *ad libitum*) and the calving cycle (which can lead to peak stock and workloads).
(iii) Animal behaviour: Such indicators refer to social behaviour, human-animal relationships and existing resting or rising behaviour.
(iv) Animal health: These indicators focus on the cause of pain and discomfort to the animal, such as extreme body condition, skin injuries and disorders, udder and teat lesions, lameness, hoof disorders, other clinical diseases and the case history of any culled animal.

A SIMPLIFIED SCORING SYSTEM FOR ASSESSING DAIRY COW WELFARE

Moran and Doyle (2015) have incorporated the key issues highlighted above into a simplified "farmer friendly" scoring system to assess dairy cow welfare. This is presented in Tables 2 and 3, and we believe it is well suited to the thousands of SHD farmers throughout tropical Asia. It contains 36 questions or observations, is based on the "five freedoms of animal welfare" and addresses both tethering and loose housing. The questionnaire is a combination of different auditing systems for dairy cattle, including those from World Society for the Protection of Animals (WSPA) (Blaszak, 2011), Assure (2010), Welfare Quality (2009) and FAO (2011). It has been developed to focus more on good rather than poor animal welfare, so the higher the score, the better the welfare for the animals. Because many SHD farmers have few milking cows, we have used 0, 30 and 90% of the herd as criteria of good stock welfare practices.

How to use this scoring system

(i) Complete the details on farm. Animal numbers are important for score calculations.
(ii) Each of the "five basic freedoms of animal welfare" are assessed.
(iii) Each measure is assigned a total of 1.0. The total for each freedom is scored according to the number of measures answered. If the measure does not apply to

Table 2. A simplified dairy farm animal welfare assessment form

Details of farm	
Farm location	
Cooperative or feedlot	
Date and time of visit	
Owner/person responsible	
Total number of milking cows on farm	
Total number of calves and heifers on farm	
Measures	**Score**
(1) Freedom from hunger & thirst	
Do all animals (including calves) have continuous access to water?	
Are all feeders and drinkers functional?	
Are feeders and drinkers clean?	
Are cows in a body condition score between 2 and 4 out of 5?*	
Do cows have a rumen score appropriate to their point of calving? *	
Are calves fed colostrum?	
Are cows fed a quality mixed ration?	
TOTAL	
(2) Freedom from discomfort	
Do cows have a cleanliness score of 2 or less out of 5?*	
Is bedding provided?	
Is bedding clean and deep enough for cows to lie comfortably?	
Can animals lie down & get up easily?	
Is there shelter from extreme weather?	
Are cows free from hock sores?	
Are cows free from pressure sores?	
Are cows free from any signs of heat stress (<70 breaths per minute)?	
TOTAL	
(3) Freedom from pain, injury and disease	
Are cows free from injuries on their bodies?	
Do cows have a locomotion score of 2 or less out of 5? *	
Are cows free from clinical disease?	
Do cows have healthy hooves (e.g. no incidences of the diseases)? *	
Do cows have clean, healthy looking udders?	
Do cows have teat scores of 2 or less out of 4? *	
Do cows have their tails intact?	
Have calves been disbudded (not dehorned)?	
Have male calves been castrated at 3 months of age or less?	
TOTAL	
(4) Freedom from fear and distress	
Do cows approach the stockperson?	
Do calves approach the stockperson?	
Will the cows let the stockperson approach within 3 m?	
Can cows be moved gently, without hitting, yelling?	
Will cows walk slowly, not run, when encouraged to move by the stockperson?	
TOTAL	

(5) Freedom to express normal behaviour
Are cows free to move (untethered?)
If tethered, are cows given access to move freely each day?
Are calves housed in appropriate groups (between 2 and 8)?
Can animals turn around fully in their cubicle?
Is there a minimum of dry lying area of 3.5 m^2 for adult cattle/bulls and 2.5 m^2 for growing heifers?
Is there evidence of normal social behaviours (limited aggressive interactions during feeding and resting)?
Are stereotypical behaviours minimal?
TOTAL

* Scoring systems fully described by Moran and Doyle (2015).

Table 3. Calculation of an animal welfare index following a farm visit.

(1) Freedom from hunger and thirst
Total number of measures recorded (A); maximum of 7
Sum of scores recorded (B)
% score for Measure 1 (A/B x 100)
(2) Freedom from discomfort
Total number of measures recorded (C); maximum of 8
Sum of scores recorded (D)
% score for Measure 2 (C/D x 100)
(3) Freedom from pain, injury and disease
Total number of measures recorded (E); maximum, of 9
Sum of scores recorded (F)
% score for Measure 3 (E/F x 100)
(4) Freedom from fear and distress
Total number of measures recorded (G); maximum of 5
Sum of scores recorded (H)
% score for Measure 4 (G/H x 100)
(5) Freedom to express normal behaviour
Total number of measures recorded (I); maximum of 7
Sum of scores recorded (J)
% score for Measure5 (I/J x 100)
(6) Farm animal welfare index
Mean value of all five % above

that particular farm (for example it may not have any young calves), this should not be taken into account in the total.
(iv) For each measure, when 'yes' applies to more than 90% of animals, 1.0 points are scored. When 'yes' applies to 30% or less of animals, 0.0 points are scored. When 'yes' applies to 30 to 90% of animals, 0.5 points are scored.
(v) Photographic standards for scoring body condition, rumen fill, cleanliness, locomotion, hooves and teat scores are provided Moran and Doyle (2015).

Once this form was developed, the next step is to make a value judgement as to the quality of animal welfare on that particular farm. This step is still evolving because we firstly need to collect sufficient on-farm data to quantify the range of farm assessment scores likely to be encountered; this may lead to some modifications and improvements in the type of data collected. Not every question can be answered for every farm, so it is not possible to develop an identical generic summary form for every farm visit. Table 3 provides a framework to calculate the animal welfare status of each farm visited. It is based on calculating a single value for each of the five freedoms then developing an overall stock welfare index based on equal weightings of each of these five freedoms.

This scoring system makes a value judgement that the five freedoms are of equal importance hence have equal impact on the cow's well-being. This assumption may require further discussion and feedback from some of the world's animal welfare experts. Table 3 is a "work in progress" but we believe it forms the basis of a relatively robust, yet quick, assessment of animal welfare on an individual small holder or large scale farm.

Other dairy cow welfare scoring systems have been developed such as Rousing et al. (2000) and Whay et al. (2003) but they require high time inputs and written records of cow performance and health, hence are more suited to larger dairy herds. We have developed a simplified system which can be completed on any small holder farms within an hour or so. Being able to quantify evidence of poor stock welfare practices is the first step in addressing these key issues on any farm. The next step is to develop strategies to improve their well-being under the existing farm conditions. For small holder dairy farmers in Asia, this is discussed at length by Moran (2012) and Moran and Doyle (2015).

Conflict of Interest

The author has not declared any conflict of interest.

REFERENCES

Assure W (2010). Advancing animal welfare assurance. Collaborative project of University of Bristol, RSPCA and Soil Association of UK.

Blaszak K (2011). WSPA Report: Dairy cattle industry and welfare in Indonesia.

Brambell FWR (1965). Report of the technical committee to enquire into the welfare of animals kept under intensive livestock husbandry systems. Command P. 2836, HMSO London, UK. PMid:14342124

European Food Safety Authority, EFSA (2009). Scientific opinion on the overall effects of farming systems on dairy cow welfare and disease. EFSA J. 1143:1-38

Farm Animal Welfare Council, FAWC (2009). Five Freedoms.

Food and Agriculture Organisation, FAO (2011). Guide to good dairy farming practices. Animal health and production guidelines no 8. FAO and IDF, Rome, Italy.

Hulsen J (2011). Cow signals. A practical guide for dairy farm management. Rood Bont Publishers, Zutphen, Netherlands. PMid:22185614.

Moberg GP (2001). Biological Response to Stress: Implications for Animal Welfare. In G. P Moberg & J. A Mench (Eds.), The Biology of Animal Stress. Wallingford, Oxon, UK: CAB International

Moran JB (2009). Key performance indicator's to diagnose poor farm performance and profitability of smallholder dairy farmers in Asia. Asian-Aust. J. Anim. Sci. 22:1709-1717. http://dx.doi.org/10.5713/ajas.2009.90201

Moran JB (2012). Managing high grade dairy cows in the tropics. CSIRO Publications, Melbourne, Australia.

Moran JB, Doyle R (2015). Cow talk. Understanding dairy cow behavior to improve their welfare on small holder farms in tropical Asia. CSIRO Publications, Melbourne, Australia.

Office International des Epizooties, OIE (2013). Terrestrial animal health code. World Organisation for Animal Health, Paris, France.

Phillips C (2002). Cattle behaviour and welfare. 2nd Ed. Blackwell Publishing, Oxford, UK. http://dx.doi.org/10.1002/9780470752418

Rousing T, Monde M, Sorensen JT (2000). Indicators for the assessment of animal welfare in a dairy cattle herd with a cubicle housing system. In Improving health and welfare in animal production, Ed Blokhuis, H. J., Ekkel, E. D. & Wechsler, B. EAAP Publication No 102:37-44.

von Keyserlingk MAG, Rushen J, de Passille AM, Weary DM (2009). Invited review: The welfare of dairy cattle - Key concepts and the role of science. J. Dairy Sci. 92:4101-4111.http://dx.doi.org/10.3168/jds.2009-2326 PMid:19700671

Webster J (2005). The assessment and implementation of animal welfare: theory into practise. In: Animal Welfare: global issues, trends and challenges. Revue scientifique et technique, Office International des Epizooties 24(2):723-734.

Welfare Quality (2009). Welfare Quality assessment protocol for cattle. Welfare Quality Consortium, Lelystad, Netherlands.

Whay HR, Main DCJ, Green LE, Webster AJF (2003). Assessment of the welfare of dairy cattle using animal-based measurements: direct observations and investigations of farm records. Vet. Rec. 153(7):197-202. http://dx.doi.org/10.1002/9780470752418

International Journal of Livestock Production