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Milk composition of Chiapas sheep breed under grazing conditions

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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

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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 $(0,\sigma_a^2)$; 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)] = $2\log(ML_k)$; Akaike information criterion (AIC) $AIC_k = -2\log(ML_k) + 2p_k$ (Akaike, 1973) and Bayesian information criterion (BIC): $BIC_k = -2\log(ML_k) + p_k \log(n)$ (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

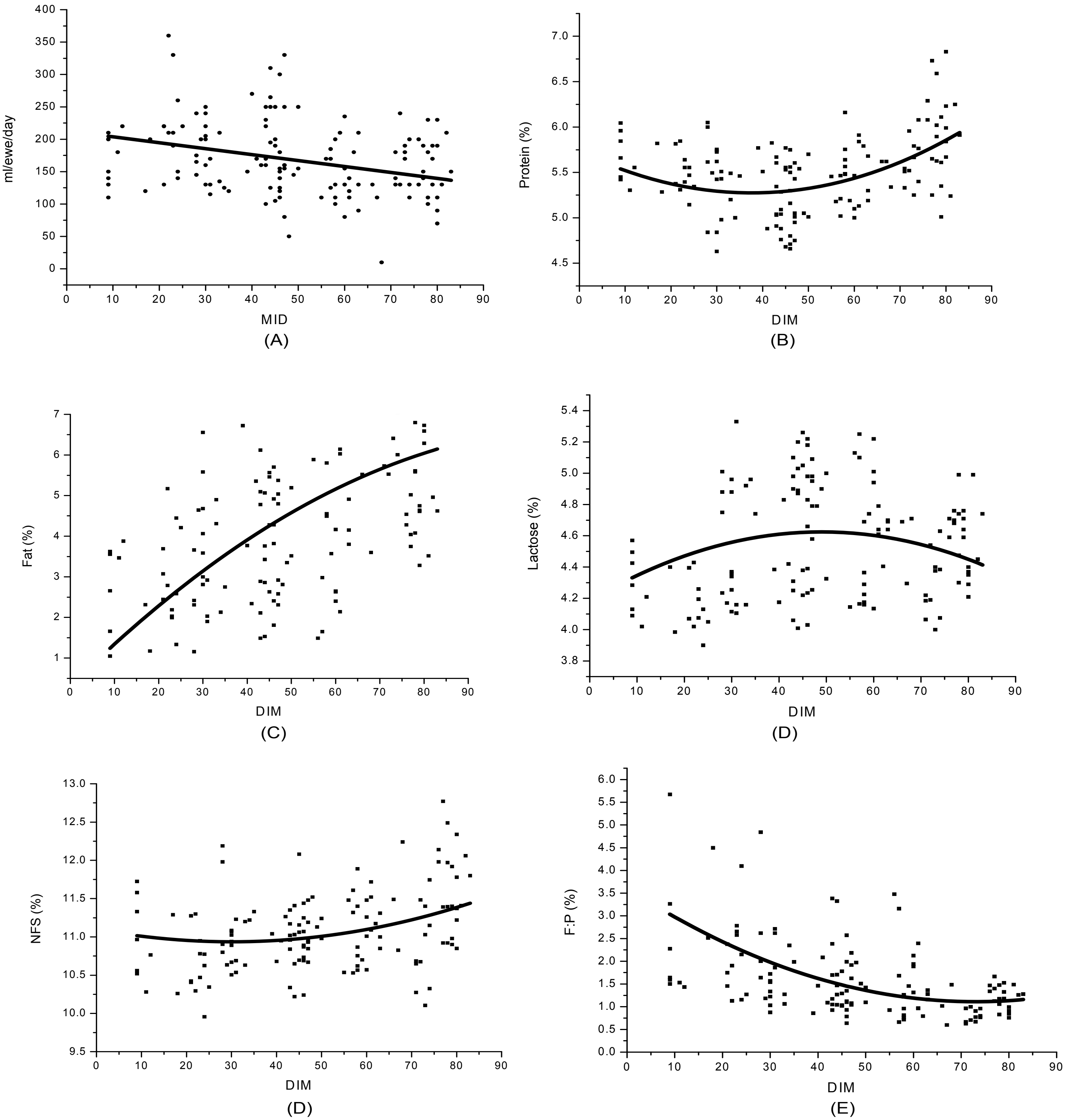

Figure 1. Scatter plot and fixed regression according to best fit Legendre polynomial for daily milk yield (A), protein % (B), fat % (C), lactose % (D), non-fatty solids % (E) and protein: fat relationship (F).

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;

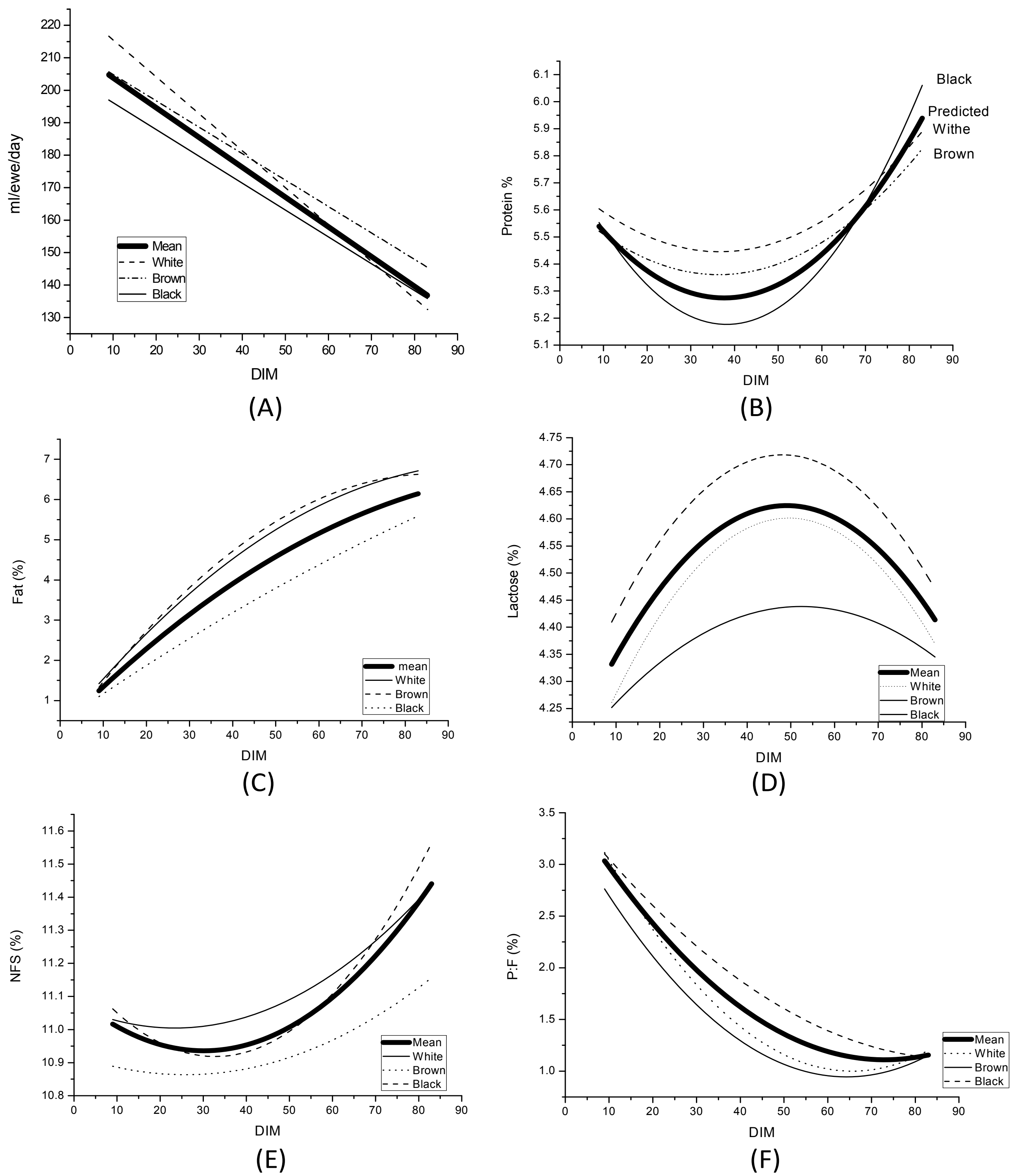

Figure 2. Mean regression of fixed model (continuous line) and random of biotype (dotted lines) for daily milk yield (ml/ewe/day) (A); protein (%) (B); fat (%) (C); lactose (%) (D); non-fatty solids (%) (E) and protein: fat relationship, mean (thick line) and by biotype (white, brown, black) in 90 days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

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