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Production systems, technical parameters and quality of bovine milk producers in southern Chile

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Abstract

J. A. Pérez. 2011. Production systems, technical parameters and quality of bovine milk producers in southern Chile. Cien. Inv. Agr. 38(1): 15-29. Production information of 29 milk producers in the southern region of Chile was studied with the objective of characterizing and classifying different dairy production systems, evaluating various associations between quantitative and qualitative studied variables and analyzing the effect of the production system and the quality of bovine milk according to the month of the year that it was processed. The classification of production groups was based on the implementation of the exploratory multivariate technique, main components analysis and conglomerates or cluster analysis. The applied statistical model was: $y_{ijk} = \mu + M_i + SP_j + MSP_{ij} + e_{ijk}$, where y_{ijk}=dependent variables (fat, protein, count of somatic cells and colony forming units); μ=general average; M_i=effect of i-th month; SP_j=effect of j-th productive system; MSP_{ij}=month-productive system interaction; e_{ijk}=random residual effect. The price per liter of milk paid to producer was discarded for the construction of groups, since they presented a low discriminatory power given a coefficient of less than 20 % variation. Different correlations between analyzed variables are discussed. Five production systems are described using the qualifying variables and original systems. In general, more intensive production systems presented lower values of fat (%) and protein (%), but showed greater superiority in the quality of sanitary milk than dairy farms with minor animal load. Regarding seasonality, as winter turns to spring, protein (%) associated with a decrease in the fat (%) increases, which determines an inverse relationship between both variables.

Key words: Cluster analysis, colony forming units, fat percentage, main components analysis, multivariable analysis, protein percentage, somatic cell.

Introduction

Production systems are characterized by a cluster of quantitative and qualitative variables affecting the soil-plant-animal relationships and through the classification of these, as a whole, the profitability of agropecuarian farms can be determined (Pérez, 2009). According to Bolaños (1999) the characterization is the description of the principal characteristics and multiple relationships of organizations; while the classification refers to the determination and construction of feasible groups based on the characteristics currently observed.

The information obtained from a characterization and classification study is considered very useful in order to propose strategies to improve aspects with a higher incidence on the develop-

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ment of the studied cattle companies (Valerio *et al*., 2004). The relevance for determining typologies to classify dairy farms is illustrated by the possibility of implementing efficient governmental policies using their statistical projections (Smith *et al*., 2002; González, 2006).

Coronel and Ortuño (2005) indicated that the appropriate knowledge from the rural producer is the basis of any research and transference process, and estimates that the classification obtained allows the detection of strengths and weaknesses which contribute to determine design priorities of economic development policies for the zones under study.

On the other hand, current dairy producers face challenges to reach levels of technical and economical efficiency to run sustainable farms within uncertain national and world dairy markets. It is sought to get the technical parameters of milk compositional, sanitary, and hygienic quality in the sections of maximum allowance, according to the payment patterns for fresh milk from the different companies of the sector (Pérez, 2009b).

The quality of compositional milk (fat and protein percentage) depends on multiple factors: genetics, seasonability, lactation days, cow age, birth season, sanitary status of the cow and nutrition (Ng-Kwai-Hang *et al*, 1984). The geographical area, climate conditions and the lactation period are known as seasonable changes affecting milk composition (Ozrenk and Selcuk, 2008). Calvache *et al.* (2009) concluded that the content of dairy solids across Chile shows a specific seasonal pattern; the seasonal fluctuations are clearer and the solid content is higher as we head further south from the Metropolitan Region; protein contents are more similar between zones during winter, but they are notoriously differentiated during spring and summer in the southern zone, which may be attributed to a positive effect of the pastured prairie. Likewise, the same authors concluded that the compositional changes are different in the case of the protein and milk fat, which demonstrates that they are affected by different factors.

The factors that may affect indicators of milk sanitary quality, like the count of somatic cells (SCC) are: udder infection, amount of affected quarters or cows, cow age, lactation days, day variation, physiological variation, season and stress (Dohoo and Meek, 1982; Salsberg *et al*., 1984; Saran and Chaffer, 2000).

Quist *et al.* (2008) mentioned that the knowledge of the variability in the fat and protein percentages, as well as in SCC is relevant in the decision making of program management in milk production.

Regarding the above, the present work is aimed to: characterize and classify different bovine milk production systems in the provinces of Llanquihue and Osorno in the South of Chile, evaluate the relationships existing among the variables studied, and analyze the effect of the productive system and the month of the year on milk quality (compositional, sanitary and hygienic).

Materials and methods

Technical information from 29 dairy producers located in the province of Llanquihue and Osorno, in Southern Chile was collected, which were grouped in a Supplier Program of a dairy plant for the zone.

The methodology applied for the characterization and classification of dairy production systems was described by Valerio *et al.* (2004). First, the selection of the sample and information processing were performed, which was obtained in 2008; then, the reduction of the variable dimension took place and finally, the classification and validation of types or groups were carried out.

A data base with different variables (quantitative and qualitative) to be analyzed, which is detailed in Table 1, was created. Variables V1 and V2 were obtained from the monthly settlements made to producers by the dairy plant. Variable V3 corresponds to all the milk produced in the farm, including the milk sent to the plant plus all the milk with other uses within the farm (milk for calves, consumption and others) during a calendar year (Fundación Chile, 2007).

The variables related to compositional (V5 and V6), sanitary (V7) and hygienic (V8) quality of milk were obtained from each of the biweekly reports provided to the producers for the twelve months in 2008, and were averaged according to the milk reception in the plant.

The proportion among liters sent to the plant in the four months, from spring to summer (November, December, January, February) and in the four months from fall to winter (May, June, July and August) was considered for the estimation of the summer-winter relation (V9), according to Fundación Chile (2007).

The farm surface (V11), the number of mass cows (V14) and the number of milk cows were obtained from direct surveys to the producers. The number of milk cows, according to the cited survey, was averaged with the figures obtained

Table 1. Quantitative and qualitative variables used for the characterization of production systems.

Quantitative variables (active)	Code	Qualitative variables (supplementary)	Code
Net income ($)	V1	Province-Llanquihue	V21-1
Reception of milk in plant (L)	V2	Province-Osorno	V21-2
Milk yield (L)	V3	Genetic-dual purpose	V22-1
Price liter of milk ($/L)	V4	Genetic-milk	V22-2
Fat % (MG)[1]	V5	Leucosis-free farm	V23-1
Protein % (PT)[1]	V6	Leucosis-not free farm	V23-0
Somatic cell count[1]	V7	Certification PABCO A[2]	V24-1
Colony forming units[1]	V8	Without certification PABCO A[2]	V24-0
Relation summer winter	V9	Official milk control-yes	V25-1
MG/PT	V10	Official milk control-no	V25-0
Milk area (ha)	V11	Type milking- herringbone	V26-1
Milk area/total area (%)	V12	Type milking-peine	V26-2
Milk yield/area ($L\cdot ha^{-1}$)	V13	Type milking-tandem	V26-3
Mass cow	V14	Type milking-classic parallel	V26-4
Mass milk cow yield (L/year)	V15	Automatic cluster remover-yes	V27-1
Milk cow yield (L/year)	V16	Automatic cluster remover -no	V27-0
Milk $cow\cdot ha^{-1}$	V17	Predipping-yes	V28-1
Milk cow/mass cow (%)	V18	Predipping-no	V28-0
Cows/milkman	V19	Teat drying-yes	V29-1
Liter/milkman	V20	Teat drying-no	V29-0
		Dipping-yes	V30-1
		Dipping-no	V30-0
		Drying therapy-yes	V31-1
		Drying therapy-no	V31-0

[1]Weighted according to reception of milk in plant; [2]PABCO: farm under official certification.

in two to three visits made to each of the producers in the year under study. The number of milkmen was confirmed by those visits in order to estimate the variables V19 (cows/milkman) and V20 (production per milkman).

Variable V22 was classified in dual purpose genetics (V22-1) or specialized in milk production (V22-2), according to the phenotypical characteristics of the dairy livestock. Variables V23 and V24 were verified according to the official documents certified by Servicio Agrícola y Ganadero (SAG) and provided by the dairy plant. All the dairy farms under analysis were brucellosis and tuberculosis-free, therefore, these were not used as variables for differentiation.

Variables V25, V26 and V27 were categorized in the field visits to all the producers. Variable V26 (type of milking parlor) was classified to the descriptions by Buxadé (1996). Characteristics V28, V29, V30 and V31 were determined according to a protocol intended to evaluate the milking and mammary health procedures in the periodical visits to the parlors.

Statistical analysis

Production systems. The reduction of the variable dimensions was carried out determining the variation coefficients from each variable, the variables presenting a low discriminatory power in the group construction were discarded. For this study, a variation coefficient higher than 20% was used as selection criteria. González (2006) and Lores *et al.* (2008) used quantitative variables with discriminatory capacity, which had a variation coefficient equal or superior than 50 and 40%, respectively. Additionally, the association degree among the variables and those variables that were highly correlated was analyzed, which was determined by one of them following the multivariate technique, according to the quotes by Valerio *et al.* (2004).

The statistical analysis was made by applying the exploratory multivariate technique of principal components analysis (ACP) and also conglomerates or cluster analysis (AC); therefore, the programs XLSTAT (Addinsoft, New York, United States, 2009) and the Statistical Analysis System (SAS, United States, 2001) were used. In the case of SAS, the procedures used were PROC PRINCOMP and PROC CLUSTER.

The types obtained were contrasted with the types existing in order to ensure that these groups were true and not simply imposed by the method used. Then, a descriptive statistics analysis was made, including mean, median, first and third quartile.

Additionally, supplementary used qualitative variables were not part of the elaboration of the principal components. The ACP analysis projects these supplementary variables on the axis determined by the other variables (active); therefore, their relation with the active variables is observed (Escofier and Pagès, 1992, cited by González, 2006).

Milk quality. The statistical model implemented was: $y_{ijk} = \mu + M_i + SP_j + MSP_{ij} + e_{ijk.,}$ where: y_{ijk}=dependent variables (% fat, % protein, SCC and CFU); μ=general average; M_i=effect of i-th month; SP_k=effect of k-ith productive system; MSP_{ijk}= month-productive system interaction; e_{ijk}=random residual effect.

The statistical analysis was made by the procedure PROC GLM of the Statistical Analysis System (SAS, United States, 2001). The data were subject to an analysis of variance to establish whether significant differences were present between treatment means, and the Tukey-Kramer test was implemented as a procedure of multiple comparisons among all the media pairs.

Results and discussion

Production systems

The variables with higher discriminatory power were determined (Table 2), the bacterial count (V8) outstands among the rest. The quantitative variables V4, V5, V6 and V10 were discarded for the group construction as they each present a low discriminatory power due to a variation coefficient lower than 20%. According to this, it is noteworthy that the price per liter of milk (V4), paid to the producer is not a variable differentiating the dairy production systems.

CER Los Lagos (2008) made a stratification of their producers by production level, obtaining minimum and maximum average sales prices of \$180 and \$202.67 (US\$ 0.29 and US\$ 0.32, in December 2008) per liter of milk, respectively. For the same year, Dünner (2009) quoted prices of \$191, \$197 and \$200 (US\$ 0.30, US\$ 0.31 and US\$ 0.32, in December 2008) per liter of milk for the producers, in order according to economical results, for the worst 25%, the average 50% and the best 25%, respectively.

Todoagro (2007) and Vidal (2009) related the margin (profit) per hectare according to the price paid per liter obtaining determination coefficients (R^2) of 0.0911 and 0.142, respectively. This is 9.11 and 14% of the total of the variance of the profit per hectare is explained by the price variability.

The frequencies of the qualitative variables are shown in Table 3. In general, and with at least 70% of frequency, the producers are from the province of Llanquihue, using dual purpose genetics, without certification PABCO A, without automatic cluster removers in the parlors, without predipping, but with dipping and drying therapy to the cows.

Table 2. Descriptive statistics of variables in study.

Variables	Unit	Media	Mínimun	Máximun	CV[1] (%)
V1	\$	112,566,196	13,144,026	389,686,126	77
V2	L	598,314	74,091	1,967,567	74
V3	L	599,894	79,028	1,969,027	73
V4	\$/L	183.52	131.40	198.05	6.8
V5	%	3.60	3.38	3.86	3.5
V6	%	3.35	3.21	3.50	2.3
V7	SCC[2]	306,739	133,897	600,460	41
V8	CFU[3]	23,821	3,935	162,026	130
V9		2.4	1.0	4.5	37
V10		1.07	1.00	1.14	2.9
V11	Ha	106	24	200	43
V12	%	60	22	100	44
V13	$L \cdot ha^{-1}$	5,564	1,331	11,538	50
V14	Cows	170	25	350	48
V15	L/year	3,330	1,452	7,276	38
V16	L/year	4,900	2,293	9,879	34
V17	$cows \cdot ha^{-1}$	1.2	0.3	2.2	41
V18	%	69	32	95	22
V19	cows/milkman	93	25	175	36
V20	L/milkman	314,194	75,551	807,675	56

[1]Variation coefficient; [2]somatic cell count; [3]colony forming units.

Table 3. Frequencies of qualitative variables[1].

Variables	Category	N°	%
V21	1	23	79.3
	2	6	20.7
V22	1	21	72.4
	2	8	27.6
V23	1	16	55.2
	0	13	44.8
V24	1	3	10.3
	0	26	89.7
V25	1	19	65.5
	0	10	34.5
V26	1	8	27.6
	2	12	41.4
	3	2	6.9
	4	7	24.1
V27	1	7	24.1
	0	22	75.9
V28	1	3	10.3
	0	26	89.7
V29	1	13	44.8
	0	16	55.2
V30	1	28	96.6
	0	1	3.4
V31	1	23	79.3
	0	6	20.7

[1]The meaning of the qualitative variables are showed in the Table 1.

The results of the ACP are shown in Tables 4 and 5. The first factorial plane of the ACP captures 64.6% of the variability present in the sample, that is, the percentage of total variability accumulated in the two first principal components reaches 64.6%. Variables V1, V2 and V3 had a correlation of 1.0 and V3 was selected as a representation of all of them. The qualitative variable locations (province), certification PABCO A, adhered to the official dairy control, teat drying use and dipping and drying therapy did not have a statistical significance with any of the active variables (Table 5).

Todoagro (2007) and Vidal (2009) indicated that the variable productions per hectare (liters of milk /ha), production by mass cow and animal load (animal units /ha) explain, in different magnitudes, the analyzed profit per hectare of the milk exploitation. In this context, the associations of different variables with V13 (milk production / surface), V15 (production mass cow) and V17 (animal load) were studied in the present work. Vidal (2009) obtained a R^2 for milk production / surface, mass cow production, and animal load with net profitability per hectare of 0.18, 0.09 and 0.15, respectively for 2008.

Table 4. Principal components analysis: active variables correlation matrix.

Variables	V3	V7	V8	V9	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20
V3	**1.0**[1]	-0.3	-0.3	-0.3	**0.7**	0.2	**0.7**	**0.8**	**0.8**	**0.4**	**0.5**	**0.6**	**0.6**	**0.9**
V7		**1.0**	0.3	**0.5**	-0.3	0.0	-0.2	-0.3	-0.3	-0.2	-0.2	**-0.4**	-0.3	**-0.4**
V8			**1.0**	**0.4**	-0.2	0.1	-0.3	-0.1	**-0.5**	-0.4	-0.2	**-0.4**	0.2	-0.3
V9				**1.0**	**-0.4**	0.2	-0.2	-0.2	-0.3	0.2	-0.3	**-0.7**	-0.2	-0.4
V11					**1.0**	**0.4**	0.1	**0.7**	**0.4**	0.0	0.0	**0.5**	**0.6**	**0.6**
V12						**1.0**	-0.2	0.0	0.2	0.3	**-0.4**	0.0	-0.1	0.1
V13							**1.0**	**0.5**	**0.8**	**0.5**	**0.8**	**0.5**	0.2	**0.7**
V14								**1.0**	0.4	0.0	**0.6**	**0.6**	**0.8**	**0.7**
V15									**1.0**	**0.7**	0.3	**0.5**	0.1	**0.8**
V16										**1.0**	-0.1	-0.1	-0.3	0.4
V17											**1.0**	**0.7**	**0.5**	**0.5**
V18												**1.0**	**0.5**	**0.7**
V19													**1.0**	**0.7**
V20														**1.0**

[1]The values in bold are different from 0 with a significance level alpha = 0.05.

Table 5. Principal components analysis: active and additional variables correlation matrix.

Variables	V3	V7	V8	V9	V11	V12	V13	V14	V15	V16	V17	V18	V19	V20
V21-1	-0.1	0.1	0.0	0.0	-0.2	0.2	-0.1	-0.3	0.0	0.1	-0.2	-0.1	-0.3	-0.1
V21-2	0.1	-0.1	0.0	0.0	0.2	-0.2	0.1	0.3	0.0	-0.1	0.2	0.1	0.3	0.1
V22-2	**0.6**[1]	-0.2	-0.1	-0.1	**0.4**	0.3	**0.4**	**0.5**	**0.6**	0.3	0.2	0.3	0.3	**0.6**
V22-1	**-0.6**	0.2	0.1	0.1	**-0.4**	-0.3	**-0.4**	**-0.5**	**-0.6**	-0.3	-0.2	-0.3	-0.3	**-0.6**
V23-1	0.3	-0.3	-0.2	-0.3	0.1	0.1	0.3	0.0	**0.4**	**0.5**	0.1	0.1	-0.2	0.2
V23-0	-0.3	0.3	0.2	0.3	-0.1	-0.1	-0.3	0.0	**-0.4**	**-0.5**	-0.1	-0.1	0.2	-0.2
V24-0	0.2	0.1	0.1	-0.2	0.3	0.2	0.0	0.2	0.1	-0.2	-0.1	0.1	0.3	0.3
V24-1	-0.2	-0.1	-0.1	0.2	-0.3	-0.2	0.0	-0.2	-0.1	0.2	0.1	-0.1	-0.3	-0.3
V25-0	-0.2	-0.1	0.4	0.3	-0.2	0.1	-0.1	-0.2	-0.1	0.1	-0.2	-0.3	-0.1	-0.1
V25-1	0.2	0.1	-0.4	-0.3	0.2	-0.1	0.1	0.2	0.1	-0.1	0.2	0.3	0.1	0.1
V26-1	**0.7**	**-0.4**	-0.2	-0.3	**0.5**	0.1	**0.5**	**0.6**	**0.5**	0.2	**0.4**	**0.5**	**0.5**	**0.7**
V26-4	-0.2	0.0	-0.1	0.1	-0.2	0.2	-0.1	-0.3	0.0	0.2	-0.2	-0.2	-0.3	-0.2
V26-2	-0.3	0.3	0.3	0.3	-0.1	0.0	-0.3	-0.1	**-0.4**	-0.3	-0.1	-0.3	-0.2	**-0.4**
V26-3	-0.2	0.1	0.0	-0.3	-0.2	-0.4	-0.1	-0.3	0.0	-0.1	-0.1	0.0	0.0	0.0
V27-1	**0.7**	**-0.4**	-0.2	-0.2	**0.5**	0.3	**0.5**	**0.5**	**0.6**	**0.5**	0.1	0.2	0.3	**0.6**
V27-0	**-0.7**	**0.4**	0.2	0.2	**-0.5**	-0.3	**-0.5**	**-0.5**	**-0.6**	**-0.5**	-0.1	-0.2	-0.3	**-0.6**
V28-1	**0.6**	0.1	-0.1	-0.1	0.2	0.1	**0.7**	0.2	**0.7**	**0.4**	**0.4**	**0.4**	0.0	**0.5**
V28-0	**-0.6**	-0.1	0.1	0.1	-0.2	-0.1	**-0.7**	-0.2	**-0.7**	**-0.4**	**-0.4**	**-0.4**	0.0	**-0.5**
V29-1	-0.1	0.2	0.3	0.2	-0.1	0.0	-0.2	-0.2	0.0	0.1	-0.3	-0.2	-0.2	-0.1
V29-0	0.1	-0.2	-0.3	-0.2	0.1	0.0	0.2	0.2	0.0	-0.1	0.3	0.2	0.2	0.1
V30-1	-0.1	0.2	0.1	0.2	-0.2	-0.1	0.0	-0.1	-0.1	0.1	-0.1	-0.3	-0.1	-0.2
V30-0	0.1	-0.2	-0.1	-0.2	0.2	0.1	0.0	0.1	0.1	-0.1	0.1	0.3	0.1	0.2
V31-1	0.2	-0.1	0.0	0.1	0.2	0.2	0.3	0.2	0.3	0.3	0.0	0.0	0.0	0.2
V31-0	-0.2	0.1	0.0	-0.1	-0.2	-0.2	-0.3	-0.2	-0.3	-0.3	0.0	0.0	0.0	-0.2

1The values in bold are different from 0 with a significance level alpha = 0.05.

The production per ha^{-1} (V13) correlated positively with V3, V14, V15, V16, V17, V18, V20, V22-2, V26-1, V27-1 and V28-1 and negatively, with V22-1, V27-0 and V28-0 (Tables 4 and 5). It may be noted from the above, the positive effect of fishbone parlor (V26-1) and the use of automatic cluster removers (V27-1) with the milk production ha^{-1} (V13), based on the negative correlation between V26-1 (fishbone parlor) and V27-1 (use of automatic cluster removers), with the SCC (V7). In general, it may be said that the studied fishbone parlors are medium line type. Garcés *et al.* (2006) estimated a highly significant correlation among the milking equipment with high milking lines and SCC (r=0.41). They indicated that the high line may have an effect on the SCC by milk reflux from the pipe to the collector, which may cause impacts from the milk drops on the health of the mammary gland.

The production per mass cow (V15) was associated positively with the variables V3, V11, V13, V16, V18, V20, V22-2, V23-1, V26-1, V27-1 and V28-1 and negatively, with V8, V22-1, V23-0, V26-2 y V28-0 (Tables 4 and 5). It is noteworthy the mean to high correlation (r=0.4, P≤0.05) of production per mass cow with leucosis-free farm (V23-1).

The animal load (V17) correlated positively with the variables V3, V13, V14, V18, V19, V20, V26-1 and V28-1, and negatively with V12 and V28-0 (Tables 4 and 5). Additionally, it may be noted the non-existent relationship between this variable (V17) and the productions per cow (V15 y V16). Smith *et al.* (2002) and González (2006) determined a correlation of 0.065 (significant) and 0.097 (non significant) between animal load and production per cow, respectively.

A variable to highlight is the summer / winter relation (V9) and its positive association with SCC (V7), that is, there may be a higher summer-winter relation for higher SCC values. This means, mammary health problems affecting the general status of the cows could cause a delay on the reproductive activity. Córdova *et al.* (2008) mentioned that both clinical mastitis and subclinical mastitis are related to the stress of the milk cow and that association hinders its reproductive performance considerably (Schrick *et al*., 2001).

The summer-winter relationship is linked to the birth season and the year, as birth takes place late in the spring season, heat (*i.e.* drought) affects milk production negatively. Therefore, in summer months, a slight increase in the SCC along with decreased milk production could take place, which might be explained by a concentration effect (Saran and Chaffer, 2000).

An additional aspect to be analyzed in the summer / winter relationship (V9) is that as it increases, a lower proportion between milk cows and mass cows (V18) will have a lower value ($r= -0.7$, $P\leq0.05$), due to a probable delay in the reproductive activity of the late birth in spring. Additionally, an association of -0.3 (non significant) was observed between V9 and V15 (production per mass cow). Smith *et al.* (2002) and González (2006) determined significant correlations of -0.377 and -0.449, respectively, between the seasonability and the production per cow. Pérez *et al.* (2007) mentioned that earlier births are associated to higher productive levels because they reach longer and persistent lactation.

The milk cows / mass cow relation (V18) was associated negatively with SCC (V7) and bacterial count and (V8), which indicates that there will be more milk cows in relation to the mass cows as there are better indicators of sanitary and hygienic quality of milk. An increase on SCC may determine hasten drying and/or eliminate cows by low production, which decreases milk cows as a consequence. Ng-Kwai-Hang *et al.* (1984) determined that high SCC are associated to low levels of milk production ($r= -0.16$). Alt (2005) determined a negative correlation between production by milk cow and SCC ($r= -0.35$, $P=0.047$) in the same geographical zone as the zone of the present study. Pedraza *et al.* (1999) concluded that milk production decreases in heifers and cows in square mode of $-0.77*\text{Range} + 0.014\ *\text{Range}^2$ and $-0.79*\text{Range} + 0.092\ *\text{Range}^2$ kg day^{-1}, respectively, for each increase range or somatic cells score (from 0 to 9). In regard to the association between the milk cow / mass cow relationship (V18) and V8 (CFU/ml), any increase in bacterial counts may be an important predisposing factor for higher SCC (the correlation between V7 and V18 is 0.3), which might result on a lower proportion of milk cows / mass cow.

The milk exploitations were classified, determining productive systems with the support of a dendrogram and the graphical representation from the principal component analysis (ACP). It is noteworthy that five groups reached the existing groups to ensure that these types were true and not imposed by the method used.

Once the group typing was obtained and verified, the types of production systems present in the zone under study were described, using classificatory and original variables. Five groups were determined, well differentiated between each other, which are synthetically described in Tables 6 and 7, and Figures 1, 2 and 3. Pérez (2009c) determined a similar number of productive typologies, but with a lower number of variables (18 quantitative and 7 qualitative).

Productive system 1 (SP1)

They are the milk exploitations which were clearly identified in the dendrogram and the ACP graphical representation, representing only 7% of the farms analyzed (Table 6). This productive system represents the more intensive milk exploitations, which is reflected by a lower summer / winter relation (V9) and a higher milk production / surface, mass cow production, animal load and milk cow / mass cow.

Smith *et al.* (2002) determined four production systems, the most intensive had averages for animal load of 1.3 UA ha^{-1}, seasonability of 1.63 and productions of 4,790 liters/ cow/ year. Dünner (2009) described the characteristics of the best 25% of producers based on the economical analysis, which were: 127 hectares for the dairy sector, 277 mass cows, milk cow/ mass cow relation of 84 %, 1,754,347 liters of annual milk production , average sale price of $200/ liter of

Table 6. Variables averages in productives systems (SP) according to analysis of conglomerates.

Variable	Unit	SP1	SP2	SP3	SP4	SP5	Total
Producer	n°	2	4	6	8	9	29
V1	$	351,802,981	198,042,714	135,472,562	29,258,504	80,193,275	112,566,196
V2	L	1,789,268	1,035,425	731,384	167,689	433,452	598,314
V3	L	1,790,.728	1,036,885	732,844	169,584	434,912	599,894
V4	$/L	196.46	191.41	185.15	173.46	184.98	183.52
V5	%	3.54	3.62	3.61	3.57	3.62	3.60
V6	%	3.39	3.29	3.31	3.33	3.40	3.35
V7	SCC[1]	2 62,719	212,711	234,794	354,827	363,529	306,739
V8	CFU[2]	9,061	12,697	15,265	40,711	22,735	23,821
V9		1.9	2.1	2.3	2.9	2.3	2.4
V10		1.04	1.10	1.09	1.07	1.06	1.07
V11	Ha	170	152	113	72	97	106
V12	%	87	59	64	66	46	60
V13	$L \cdot ha^{-1}$	10,703	6,900	6,664	2,637	5,697	5,564
V14	cows	276	262	209	79	160	170
V15	L/year	6,628	4,051	3,648	2,293	2,985	3,330
V16	L/year	7,518	4,994	5,399	4,504	4,297	4,900
V17	$cw^{3} \cdot ha^{-1}$	1.4	1.4	1.3	0.7	1.3	1.2
V18	%	88	82	70	55	70	69
V19	cows/m[4]	111	131	105	69	86	93
V20	L/m[4]	731,278	518,442	366,422	147,640	239,418	312,784

[1]Somatic cell count; [2]colony forming units; [3]cows; [4]milkman.

Table 7. Frequencies (%) qualitative variables according to productive system (SP).

Variables	Category	SP1	SP2	SP3	SP4	SP5	Total
V21	1	100	75	50	100	78	79
	2	0	25	50	0	22	21
V22	1	0	50	50	100	89	72
	2	100	50	50	0	11	28
V23	1	100	50	67	38	56	55
	0	0	50	33	63	44	45
V24	1	0	0	0	13	22	10
	0	100	100	100	88	78	90
V25	1	50	100	67	50	67	66
	0	50	0	33	50	33	34
V26	1	100	75	50	0	0	28
	2	0	0	50	50	56	41
	3	0	0	0	0	11	3
	4	0	25	0	50	33	28
V27	1	100	50	50	0	0	24
	0	0	50	50	100	100	76
V28	1	100	0	0	0	11	10
	0	0	100	100	100	89	90
V29	1	100	25	0	63	56	45
	0	0	75	100	38	44	55
V30	1	100	75	100	100	100	3
	0	0	25	0	0	0	97
V31	1	100	75	83	50	100	79
	0	0	25	17	50	0	21

milk (US$ 0.32, by December 2008), animal load of 2.5 UA ha^{-1}, 6,193 liters of production per mass cow, 1.3 of summer winter relation and production of 15,192 liters ha^{-1}.

The farms working with this system (SP1) presented the highest economic incomes obtaining the best prices per liter of milk paid to the producer, supported by the reception volumes of milk in plant, optimal parameters of SCC and CFU, and because they are farms free from brucellosis, tuberculosis and leucosis.

In regard to the qualitative variables, the farms grouped in SP1 used genetics specialized in milk production (V22-2), they had fishbone parlors (V26-1) with automatic cluster removers (V27-1) and carried out predipping (V28-1). According to what was previously expressed, variables V26-1 and V27-1 presented negative correlations with SCC (V7), which is coherent with milk sanitary and hygienic quality.

Productive system 2 (SP2)

The farms included in this system represented 14% of the total of farms studied, they are semi-intensive, with lower levels of V13, V15 and V18 and higher of V9 (cows / milkman), when they are compared with the farms in SP1. The lower milk production ha^{-1} and per mass cow may be explained because these farms have a seasonability of 2.1 (V9), 50% of the milk livestock are composed of double purpose races (V22-1), 75% have fishbone parlors (V26-1) with automatic cluster removers (V27-1). They presented values of milk quality (V7 and V8) with which they achieved the maximum bonus level according to the payment patterns of the dairy plants in the zone. Additionally, they had a cow per milkman relation (V19) superior to 109 and inferior to 131, and 204 cows per milkman described for Chile, New Zealand and Australia, respectively (Carter and Vidal, 2009).

Productive system 3 (SP3)

This includes 20% of the exploitations analyzed. They represent average values of the different quantitative variables, close to the mean of the total of farms under study. They outstand by having a good compositional quality (V5, V6), and milk sanitary and hygienic quality (V7 and V8). They have the challenge of improving milk production per mass cow and the proportion of milk cows / mass cow.

Productive system 4 (SP4)

These are the smallest and more extensive milk farms due to their higher summer / winter relation (V9) with lower values of the technical parameters V13, V15, V17, V18, V19 and V20, and they present regular indicators of milk quality (V7 and V8). These farms represent 28% of the dairy exploitations studied. From the total of dairy farms (in this group 8), 25% have a seasonability higher than 3.6, 25% do not exceed 1,915 liters of production mass cow and 75% have a milk cow / mass cow proportion of up to 64% (Figures 1, 2 and 3). All the above may explain that they are the operations obtaining the

Table 8. Analysis of variance for statistical models (Probability > F).

Dependent variable	Model	R^2 [1]	Month	SP[2]	Month-SP
Fat	<0.0001	0.41	<0.0001	0.0193	0.9988
Protein	<0.0001	0.39	<0.0001	<0.0001	0.6802
SCC[3]	0.0003	0.29	0.4420	<0.0001	1.0
CFU[4]	0.8642	0.14	0.2439	0.0763	0.9632

[1]Determination coefficient; [2]productive system; [3]somatic cell count; [4]colony forming units.

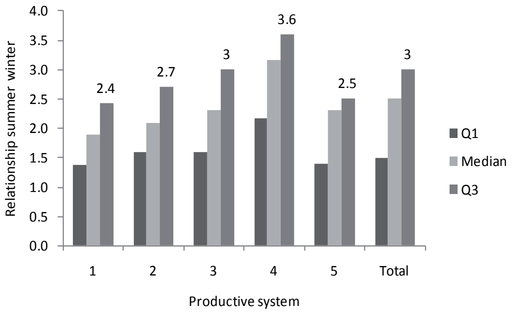

Figure 1. Position statistics for the seasonality according to productive system (labeled data indicate Q3).

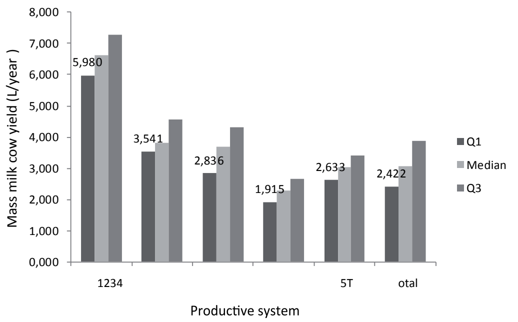

Figure 2. Position statistics for the production cow mass (L/year) according to productive system (labeled data indicate Q1).

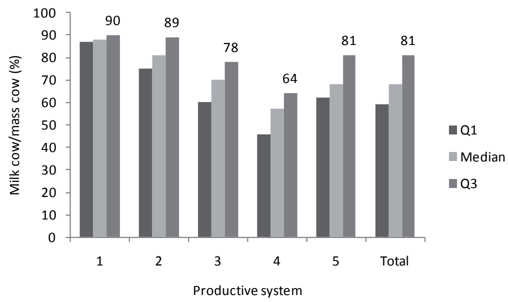

Figure 3. Position statistics for the milk cow/mass cow (%) according to productive system (labeled data indicate Q3).

lowest purchase prices of milk paid to the producer, which are possibly the most vulnerable to pessimistic scenarios of the markets.

Smith *et al*. (2002) determined that the most extensive system an average animal load of 0.57 UA ha^{-1}, a seasonability of 3.53 and a production per cow of 1,016 liters / cow / year. Dünner (2009) detailed in an economic study the characteristics of 25% of deficient producers. They had a milking surface of 149 hectares, 243 mass cows, a milk cow / mass cow relation of 81 %, 1,373,697 liters of annual milk, an average price of $191 / liter of milk, a load of 1.8 UA ha^{-1}, 5,066 liters of mass cow production, a summer winter relation of 1.5, and a production per hectare of 9,263 liters.

The farms in SP4 had double purpose cattle (V22-1). They are the least technified dairy systems, as only 50% had modified fishbone parlors (V26-2) and the other 50% classic parallel (V26-4). Additionally, they did not have automatic cluster removers.

Productive system 5 (SP5)

They represent the group of higher representation with 36% of the productive systems examined. The producers of this group had the best indicators of compositional quality (V5 and V6), but high values of SCC (V7). 25% of the dairies farms of this group did not exceed a mass cow production of 2,633 liters a year (Figure 2) and with a milk cows / mass cow relation of only 62 % (Figure 3).

Milk quality

The results of the analysis of variance for the different dependent variables are shown in Table 8, according to the statistical model implemented. The fat models, protein and SCC had a high significance. The productive system (SP) had a remarkable effect on the protein percentage, SCC and fat percentage and a tendency with CFU. The seasonability (month of the year) also affects fat and protein percentages.

The Least Square Means for the different dependent variables under study are shown in Table 9, according to the productive system. Only the means showing statistical differences are analyzed below. In percentage of fat, the farms in SP1 showed values lower than the farms in SP3 and SP5, which may be explained by the higher production per mass cow of SP1. The increased volume of milk per animal normally entails diminished total solids, even though the total kilos of protein and fat may be superior at the end of lactation, if it is compared to lower production cows, with more concentrated milk. It may be also due to the genetics used, as the group in SP1 has genetics specialized on milk production (Table 7). Montaldo *et al.* (2009) mention fat values (%) for Holstein of 3.63% and 3.66% in Overo Colorado.

In regard to protein, the farms in SP1 and SP5 had higher levels than farms SP2 and SP3. The higher percentage of protein from milk plants in SP5 may be related to the genotypes used. Montaldo *et al.* (2009) indicated protein values for Holstein and Overo Colorado of 3.23% and 3.31%, respectively.

The highest variances among the different productive systems studied appear in milk sanitary quality (SCC). The farms in SP1, SP2 and SP3 had a better status of mammary health than the farms in SP4 and SP5, which may explain, among other reasons, the low productive levels for SP4 and SP5. Pérez (2009) studied similar productive systems in three seasons and determined significant differences in the SCC and the bacterial counts from farms classified as SP1, in comparison to the farms in SP4 and SP5. That is, farms with more intensive productive systems might have more effective routine milking procedures and cleaning equipment than milk systems with minor animal load. Remarkable control measures are: hygiene during milking, teat disinfection (dipping), drying therapy, milking equipment functioning, elimination of chronic cases, control of purchased cows and heifers and nutrition of dry and lactating cows. Only 50% of the producers in the farms from system SP4 used drying therapy (Table 7).

The dynamics of the dependent variables studied according to the season of the year are shown in Table 10. It may be observed that the highest fat values would appear from March to July, with statistical significance and with a mean value of determination coefficient (R^2=0.41). Calvache *et al.* (2009) determined that the fat percentages are higher in June in different regions of Chile: Valparaíso and the Metropolitan Region, 3.7%; Bío Bío, Maule and O'Higgins, 3.9%; Araucanía, Los Ríos and Los Lagos, 4.0%. In a three-year study with Holstein cattle in the United States, the highest levels in fat occurred in the fall and winter seasons (Wattiaux, 2008). Ng-Kwai-Hang *et al.* (1984), Buxadé (1996) and Sargeant *et al*. (1998) mentioned that the season of the year affects milk composition, especially the fat content: the percentages in fat increase in periods of short days (fall).

The lowest fat contents occurred in October, which is coherent with data by Calvache *et al.* (2009). Wattiaux (2008) indicated that the diminished milk fat may be explained by a low proportion of the acetate: propionate relation in the rumen, attributed to a higher amount of propionate. This amount is directly related to the higher contributions of non structural carbohydrates recorded in spring in permanent prairies under pasture. It may be also associated to a deficit of neutral detergent fiber in the ration of shepherding systems, which affects the acetate ruminal production negatively.

October seems to be critical by the dramatically decreased fat percentage and an increased protein percentage, which determines an inverse relation between them, even with values lower

Table 9. Least Squares Means for fat, protein, Somatic cell count (SCC) and Colony forming units (CFU) according productive system (SP).

Productive system (SP)	Fat (%)	Protein (%)	SCC[1]	CFU[2]
SP1	3.56 a[3]	3.38 a[3]	273,233 a[3]	9,995 a[3]
SP2	3.62 ab	3.26 b	219,475 a	12,927 a
SP3	3.66 b	3.31 bc	237,697 a	16,229 a
SP4	3.62 ab	3.34 ac	370,126 b	39,694 a
SP5	3.65 b	3.41 a	368,304 b	23,436 a

[1]Somatic cell count. [2]Colony forming units.
[3]Different letters in each column indicate significant differences according to Tukey-Kramer test (P≤0.05).

Table 10. Least Squares Means for fat, protein, SCC and CFU according to month in the year.

Month	Fat (%)	Protein (%)	MG/PT[1]	SCC[2]	CFU[3]
January	3.58	3.32	1.08	306,386	26,688
February	3.64	3.30	1.10	314,330	34,438
March	3.87*	3.35	1.16	309,595	11,637
April	3.82*	3.38*	1.13	297,881	12,189
May	3.71*	3.38*	1.10	292,097	15,213
June	3.66	3.34	1.10	289,477	14,886
July	3.70 *	3.28	1.13	296,651	20,000
August	3.56	3.27	1.09	307,625	23,316
September	3.46	3.33	1.04	320,485	47,736
October	3.40**	3.43*	0.99	252,866	9,203
November	3.49	3.43*	1.02	245,027	12,377
December	3.55	3.29	1.08	292,784	17,790

*=P≤0.05; **=P≤0.08: statistics tendency.
[1]Fat/protein.
[2]Somatic cell count.
[3]Colony forming units.

than 1 (0.99 in October, Table 10). The maximum value observed was 1.16 (March). Wattiaux (2008) indicated minimum values of 1.20, 1.28 and 1.20 and maximum values of 1.31, 1.36 and 1.39 for the races Pardo Suizo, Jersey and Holstein, respectively.

According to the above, we may conclude that the price per liter paid to the producer is not a variable which differentiates the production systems. A positive effect was obtained from fishbone parlor and the use of automatic cluster removers with the milk production ha^{-1}, which may be explained by the negative correlation presented by these variables with the count of somatic cells. A higher summer-winter relation was associated to a smaller proportion milk cows and mass cows and higher values of SCC and CFU. The production systems may be differentiated, among other indicators, by the animal load and by milk production ha^{-1}. 28% of the producers studied (SP4) presented deficient production parameters, like low animal loads, milk production per hectare and mass cow production. In regard to milk quality, it may be concluded that the more intensive production systems presented lower values in fat (%) and protein (%) but showing superiority in the sanitary milk quality (SCC) than the most extensive exploitations. An increase of protein content (%) occurs from winter to spring, associated with a decreased fat percentage, which determines an inverse relation between both variables.

Resumen

J. A. Pérez. 2011. Sistemas productivos, parámetros técnicos y calidad de leche bovina de productores del sur de Chile. Cien. Inv. Agr. 38(1): 15-29. Se procesó información productiva de 29 productores de leche de la zona sur de Chile, con el fin de tipificar y caracterizar diferentes sistemas productivos lecheros, evaluar las asociaciones entre las variables cuantitativas y cualitativas estudiadas y analizar el efecto del sistema productivo y mes del año en la calidad de leche. La tipificación de grupos productivos se fundamentó en la aplicación de la técnica multivariable exploratoria análisis de componentes principales y análisis de conglomerados o cluster. El modelo estadístico aplicado fue: $y_{ijk} = \mu + M_i + SP_j + MSP_{ij} + e_{ijk}$, donde y_{ijk}=variables dependientes (materia grasa, proteína, recuento de células somáticas, y unidades formadoras de colonias); μ=promedio general; M_i= efecto del i-ésimo mes; SP_j=efecto del j-ésimo sistema productivo; MSP_{ij}=interacción mes-sistema productivo; e_{ijk}=efecto residual aleatorio. El precio de litro de leche pagado a productor se descartó para la construcción de grupos, por presentar un bajo poder discriminatorio dado un coeficiente de variación menor a un 20%. Se explican las diferentes correlaciones entre las variables analizadas. Se describen cinco sistemas productivos haciendo uso de las variables clasificatorias y originales. En general, los sistemas productivos más intensivos presentaron menores valores en materia grasa (%) y proteína (%), pero mostraron una superioridad en calidad sanitaria de leche que las explotaciones lecheras más extensivas. Respecto a la época del año, de invierno a primavera se produce un aumento de la proteína (%) asociado a una disminución de la materia grasa (%) lo que determina una relación inversa entre ambas variables.

Palabras clave: análisis de componentes principales, análisis de conglomerados, análisis multivariable, porcentaje de materia grasa, porcentaje de proteína, recuento de células somáticas, unidades formadoras de colonias.

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