Typification of a fresh goat cheese of Mexico by path models

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Abstract: The purpose of this study was to typify goat cheese and determine the relationship among climatic factors, production systems, milk quality, and their impact on the physicochemical, instrumental, and sensory properties and consumer preference by path models. Using the regression partial least square technique coupled to multiple factor analysis, two models were established. These models showed that the production system directly affected the physicochemical quality and indirectly affected instrumental and sensory parameters, which explained the preference and classification of the cheeses. The proposed methodology is expected to generate useful information enabling the establishment of potential fresh goat cheese produced in a specific geographic zone as a distinctive brand.

Key words: Cheese, physicochemical analysis, sensorial characterization, consumer attitudes, path models

1. Introduction

Traditional cheeses linked to a territory are the result of processing techniques where the collective knowledge arises from physical-biological and human factors (1) and their interactions (2). Achieving its typicity is important to allow for legal protection to develop its market (3). The typicity is established by integration of information ranging from the milk production system, milk characteristics, cheese-processing parameters, and physicochemical, microbiological, and sensory characteristics (1). Some artisanal cheeses made with goat milk are part of the cultural heritage and represent an important nutritional alternative (4). Considering the importance of these typical products, several studies focused on establishing their typicity (4–7). Such studies are complex; however, it is possible to explain and quantify the relations of variables through path models using the regression partial least square (PLS) path analysis technique (8). In the central mountain area of Veracruz in Mexico, fresh goat milk cheese represents the main source of income for some families, so there is interest in obtaining a collective trademark; however, no information is available to establish the typicity. The aim of this research was to establish the typicity and determine the relationships among climatic factors, production systems, milk quality, and their impact on the physicochemical, instrumental, and sensory properties and consumer preference by path models.

2. Materials and methods

2.1. Study area and climatic conditions (CC)

Four goat production units (GPUs) were studied in the central mountain area of the State of Veracruz, Mexico. The GPU information of different municipalities with respect to altitude (ALT) in meters above sea level (m a.s.l.), average temperature (AT) in °C, annual pluvial precipitation (APP) in mm, production system (PS) semistabled (SST) or stabled (ST), and feeding (FD) is shown in Figure 1.

2.2. Cheese making process

Raw milk was received in cheese dairies, filtered, and pasteurized. Lyophilized lactic cultures of *Lactococcus lactis* and *Lactococcus cremoris* were added at 37 °C, the milk was curdled with calf liquid rennet (30 mL/100 L milk), and the curd was cut with a knife, pressed into plastic molds for 7 h (1 kg 2 kg^{-1} of force), held in a brine (28% salt), and stored at room temperature (25 ± 2 °C) for 2 days.

2.3. Sampling

The milk used for the fresh goat cheese was obtained from goats of Alpine and Saanen breeds, milked manually.
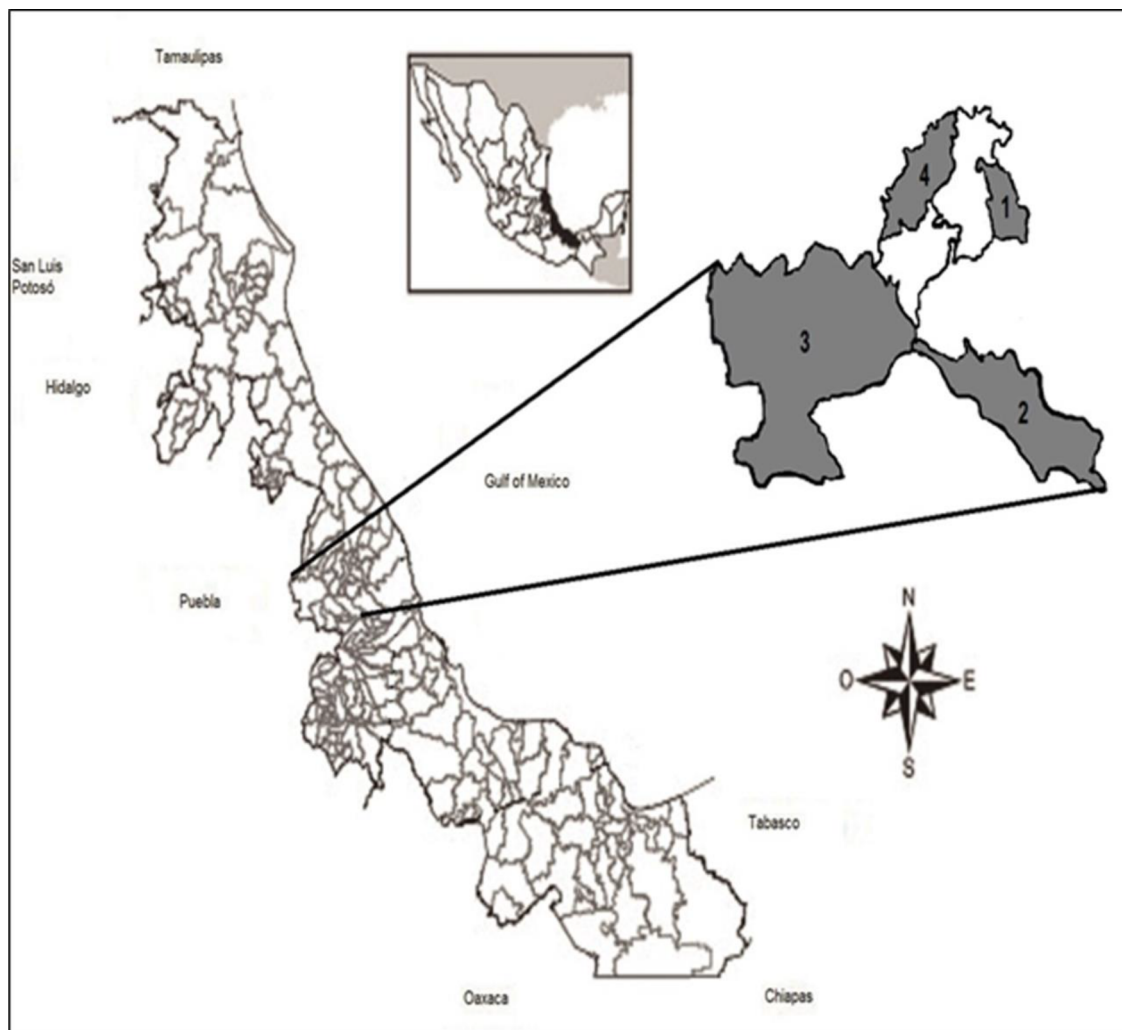
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Figure 1. Geographical delimitation of the study area. 1) Cocoatzintla, ALT: 1430 m a.s.l., AT: 12.5 °C, APP: 1780 mm, PS: SST, FD: Star grass (*Cynodon plectostachyus*), King grass (*Saccharum sinense*); 2) Coatepec, ALT: 1208 m a.s.l., AT: 18 °C, APP: 1500 mm, PS: ST, FD: morera (*Morus alba*), orange peels (*Citrus sinensis*). 3) Perote, ALT 2400 m a.s.l., AT: 12 °C, APP: 494 mm, PS: ST, FD: alfalfa (*Medicago sativa*), corn stover (*Zea mays*). 4) Tatatila, ALT: 1867 m a.s.l., AT: 20 °C, APP: 1346 mm, PS: SST, FD: bellotas (*Quercus ilex*), Kikuyo grass (*Pennisetum clandestinum*).

Twelve milk samples of 500 mL from the storage tank, after pasteurization, were taken using borosilicate sterile glass bottles. Twenty cheese samples of 1 kg were collected in sterile bags. Samples stored at 4 ± 1 °C were transported to the laboratory within 2 ± 0.25 h for further analysis (9).

2.4. Chemical composition of milk
Fat, protein, lactose, nonfat solid (NFS) contents, density, and cryoscopy in milk at 20 ± 0.5 °C was tested with Lactoscan S equipment (Milkotronic Ltd., Nova Zagora, Bulgaria). Acidity (g L^{-1} lactic acid) was determined (10).

2.5. Microbiological analysis of milk
Milk samples of 10 mL in 90 mL of sterile peptone were homogenized for 1 min at 265 rpm in a homogenizer (Stomacher Model 400 Circulator, Seward Limited, West Sussex, UK). Aerobic mesophilic (AM) bacteria, total

coliform (TC) bacteria, *Escherichia coli* (EC) plate count, *Staphylococcus aureus* (SA) (10), *Salmonella* spp. (SS) (11), and *Brucella melitensis* (BM) (12) were determined. The results were transformed to log$_{10}$ scale for subsequent analyses.

2.6. Chemical composition of cheese
Fat, moisture, protein, and ash contents were determined (10). The pH, with a potentiometer (Hanna Instruments, Hanna HI 98230, Padua, Italy), and water activity (a$_w$), with Pawkit equipment (Decagon Devices, Inc., Pullman, WA, USA), were determined.

2.7. Microbiological analysis of cheese
Cheese samples of 10 g in 90 mL of sterile peptone were homogenized for 1 min at 265 rpm in a homogenizer (Stomacher). The AM, TC, EC, SA, fungi count (10), and

SS (11) were determined. The results were transformed to $\log_{10}$ scale for use in subsequent analyses.

2.8. Instrumental texture analysis of cheese

Hardness, cohesiveness, adhesiveness, gumminess, chewiness, and elasticity of cylindrical cheese samples of 3.0 cm in diameter and 5.0 cm in height were determined. The samples were taken at 1.0 cm from the surface to reduce the dryness effect (3). A texturometer (Estable Micro Systems, Model TA-XT, Vienna Court, UK) with a load cell of 5 kg and a speed of 1 mm s^{-1} using an aluminum disk 75 mm in diameter (P/75) was used.

2.9. Color analysis of cheese

A colorimeter (UltraScan Vis, Hunter Associates Laboratory Inc., Reston, VA, USA) was used to measure the color parameters. The CIELAB coordinates (L*, a*, and b*) were determined. The chromaticity (C*) and hue angle (h°) were calculated.

2.10. Sensory characterization of cheese

A panel of six judges was trained to evaluate the following attributes: white color (WHCO), porous surface (POSU), presence of serum (PSER), firmness to the touch (FITO), creamy to the touch (CRTO), citrus odor (CIOD), serum odor (SEOD), salty (SALT), acid (ACID), firmness in mouth (FIMO), goat aroma (GOAR), milk aroma (MILA), citrus aroma (CIAR), serum aftertaste (SEAF), milk aftertaste (MIAF), fat aftertaste (FTAF), and goat aftertaste (GOAF). An unstructured scale from zero to nine, where 0 = low intensity and 9 = high intensity, was used (13).

2.11. Consumer study

A study of consumers at the market for organic products in the city of Coatepec, Veracruz, Mexico, was conducted. Eighty consumers were selected (38 men and 42 women, between 27 and 54 years old) to determine preferences. A hedonic scale of nine points, where 1 = disgusts me extremely and 9 = I like it extremely, was used (4).

2.12. Statistical analysis

The effect of GPU on the milk and cheese characteristics was determined by general linear models of the statistical software SAS (SAS Institute Inc., Version 9.3, Cary, NC, USA). Attributes' sensory data by analysis of variance (ANOVA) with three factors (product, judge, repeat) and interaction (product × judge) were evaluated (7). Results of the consumer study by two-factor ANOVA (consumer and product) were evaluated and grouped by the technique of ascending hierarchical classification (AHC) with the Ward method. The interactions between constructs using path modeling by regression PLS coupled with multiple factor analysis (MFA) were established. In the path models the variables of CC (altitude, precipitation, and temperature), PS (ST, SST), feeding type, milk composition (MILC), cheese composition (CHC), instrumental parameters (INS) (color and texture), sensorial attributes (SEN),

and consumer groups were included for shaping of the constructs. The variables with correlation of >0.70 were included in MFA, considering CC and PS as supplementary variables. Validation of models was evaluated by the correlation between each variable and its construct, and the convergent validity of each construct was evaluated by analysis of extracted variance; evaluation of structural model trough β and R^2, path and determination coefficients, respectively; and determination of the goodness of fit between the measurement model and structural model (8). The MFA, AHC, and PLS were determined using XLSTAT 2009 software (Addinsoft, New York, NY, USA).

3. Results and discussion

3.1. Chemical composition of milk

The chemical components analyzed showed differences (P < 0.05) among milks (Table 1). The milk of Coatepec showed the highest values for fat, protein, lactose, and density, as well as lower values of cryoscopy. The milk of Tatatila showed lower values of protein, lactose, NFS, and density and the highest values of cryoscopy. The elevated fat content could be related to high fiber content in the diet of goats and the essential oils in orange peels (15). The low solids contents in the milk of Tatatila are related to deficient feeding (16) and could even signal a possible adulteration by water addition (15).

3.2. Microbiological analysis of milk

Significant differences (P < 0.05) were observed among the milks of different dairies for all microbiological values (Table 1). The AM in the milk of Coacoatzintla exceeded the regulatory limit of 4.47 log CFU mL^{-1} (17). For TC count, the milks of Coacoatzintla and Perote exceeded the limit of 1.00 log CFU mL^{-1} (18). No milk presented EC, SA, SS, or BM. The AM and TC counts may be related to inappropriate sanitary management or postpasteurization contamination (19). The absence of EC, SA, and SS may be due to the pasteurization of milk (19) and the absence of BM was consistent with the low prevalence reported for the municipalities of Perote and Jalancingo (20).

3.3. Chemical composition of cheese

Table 2 shows significant differences (P < 0.05) with respect to chemical composition. Perote cheeses had the highest fat content and lowest moisture content while Tatatila cheeses had the lowest values of fat and the highest protein content compared to the rest of the cheeses. The a$_w$ value was highest in the cheeses of Coatepec; however, no significant differences were found among the cheeses studied. The pH value was highest in the cheeses of Perote and Tatatila. The protein, fat, and moisture contents and pH values observed were within the range reported in cheeses of goats supplemented with oils of *Cnidoscolus quercifolius*, *Sesamum indicum* L., and *Ricinus communis*

Table 1. Chemical composition (%), density (kg m^{-3}), cryoscopy (°C), and microbiological count (log CFU mL^{-1}) of milk in different cheese dairies.

Parameter	Coacoatzintla	Coatepec	Perote	Tatatila
Fat	3.46 ± 0.01[a]	5.82 ± 0.02[d]	3.56 ± 0.01[b]	5.26 ± 0.01[c]
Protein	2.47 ± 0[c]	2.59 ± 0.01[d]	2.39 ± 0.1[b]	1.38 ± 0.01[a]
Lactose	4.04 ± 0.01[b]	4.54 ± 0.01[d]	4.15 ± 0.01[c]	2.71 ± 0.01[a]
NFS	7.23 ± 0.01[a]	7.91 ± 0.02[b]	7.41 ± 0.01[c]	4.56 ± 0.01[d]
Density	1024.1 ± 0.03[b]	1025.2 ± 0.05[d]	1024.7 ± 0.04[c]	1013.3 ± 0.01[a]
Cryoscopy	−0.490 ± 0.01[c]	−0.570 ± 0.00[a]	−0.500 ± 0.00[b]	−0.320 ± 0.00[d]
Acidity	2.33 ± 0.00[a]	2.71 ± 0.07[b]	2.40 ± 0.11[a]	1.90 ± 0.05[c]
AM	4.72 ± 0.01[c]	1 ± 0.00[a]	3.53 ± 0.08[b]	1 ± 0.00[a]
TC	3.38 ± 0.12[b]	1 ± 0.00[a]	4.63 ± 0.04[c]	1 ± 0.00[a]
EC	ND	ND	ND	ND
SA	ND	ND	ND	ND
SS	ND	ND	ND	ND
BM	Negative	Negative	Negative	Negative

NFS: Nonfat solids, AM: aerobic mesophilic, TC: total coliform, EC: *Escherichia coli*, SA: *Staphylococcus aureus*, SS: *Salmonella* spp., BM: *Brucella melitensis*, ND: not detected. [a, b, c, d]: Superscripts corresponding with homogeneous groups given by LSD Tukey test (P < 0.05).

Table 2. Chemical composition (%), a_w, pH, and microbiological count (log CFU g^{-1}) of the fresh cheeses made in different cheese dairies.

Parameter	Coacoatzintla	Coatepec	Perote	Tatatila
Fat	20.57 ± 0.42[b]	18.73 ± 0.25[a]	22.07 ± 0.2[c]	18.67 ± 0.23[a]
Protein	22.23 ± 0.22[b]	21.66 ± 0.16[a]	22.65 ± 0.13[c]	25.93 ± 0.16[d]
Moisture	50.19 ± 3.70[b]	47.04 ± 1.40[b]	39.90 ± 4.00[a]	47.40 ± 0.36[b]
Ash	5.01 ± 0.10[a]	2.42 ± 0.08[b]	4.83 ± 0.17[a]	3.54 ± 0.05[c]
a_w	0.92 ± 0.00[a]	0.95 ± 0.00[a]	0.92 ± 0.01[a]	0.93 ± 0.01[a]
pH	6.36 ± 0.01[a]	6.33 ± 0.01[b]	6.38 ± 0.02[c]	6.38 ± 0.01[c]
AM	4.84 ± 0.04[a]	3.08 ± 0.03[b]	3.85 ± 0.06[c]	4.20 ± 0.05[d]
TC	ND	ND	ND	ND
EC	ND	ND	ND	ND
SA	ND	ND	ND	ND
Fungi	1.15 ± 1.62[a]	3.05 ± 0.08[a]	3.60 ± 0.13[a]	2.23 ± 0.33[a]
SS	ND	ND	ND	ND

a_w: Water activity, AM: aerobic mesophilic, TC: total coliform, EC: *Escherichia coli*, SA: *Staphylococcus aureus*, SS: *Salmonella* spp., BM: *Brucella melitensis*, ND: not detected. [a, b, c, d]: Superscripts corresponding with homogeneous groups given by LSD Tukey test (P < 0.05).

L. (5). The variability in composition has been linked to milk composition and cheese-processing conditions (3).

3.4. Microbiological analysis of cheese

Microbiological counts of the cheeses are presented in Table 2. Coacoatzintla cheeses exceeded the maximum value of 4.47 log CFU g^{-1} established for AM at the quality standard. Coatepec and Perote cheeses exceeded the regulatory maximum value for fungi counts of 2.69 log CFU g^{-1} (18). High levels of AM could be related to the microbiological quality of milk and sanitation during cheese making (4). The presence of TC, EC, SA, and SS was not detected, maybe due to competition with the starter culture (21).

3.5. Instrumental texture analysis of cheese

Significant differences (P < 0.05) in textures of the cheeses were found, except in cohesiveness and elasticity for Coacoatzintla, Perote, and Tatatila (Table 3). The cheeses of Perote and Coatepec were the hardest, most gummy, and more chewable, with lower values of adhesiveness. The cheeses of Coatepec were more elastic and cohesive. High hardness values in the cheeses of Coatepec and Perote could be due to low moisture content caused by syneresis (22). Some features of texture in the cheeses of Coatepec could be related to an increase in the solubility of the casein micelles and decrease of calcium in the whey during the curd stage, which generates greater malleability (5). The cheeses of Perote and Coatepec showed high values for gumminess and chewiness with significant differences (P < 0.05) in relation to the chesses of Tatatila and Coacoatzintla, and this effect is consistent with those reported in other studies (23). High cohesiveness in all

chesses studied is related to the fiber and oil in the diet of goats (5).

3.6. Color analysis of cheese

The color parameters are shown in Table 3. The cheeses of Coatepec and Coacoatzintla showed the highest L* values (P < 0.05); this was due to greater refraction of light by water contained since these cheeses had high values of moisture content (14). The hue angles ranged from 79.81° to 85.62°, indicating a tonality close to light yellow (90°) with differences in all cheeses studied, except those of Coatepec and Tatatila. Saturation (C*), which ranged from 10.09 to 13.27, did not present significant differences between them, except the cheese of Perote. The color of the cheeses was similar to that reported in other studies (13). The yellow tonality (b*) in the cheeses of Perote, Tatatila, and Coatepec may be related to the fat-soluble vitamins, retinol, β-carotene, and essential oils contained in goat feed (24).

3.7. Sensory characterization of cheese

ANOVA with interaction of three factors revealed significant differences (P < 0.05) among the cheeses for all attributes. The judge × repetition interaction showed that the panel was consensual in the evaluation of the attributes. Figure 2 showed that the cheeses of Coacoatzintla and Tatatila had higher intensities for the attributes WHCO, PSER, SEOD, SALT, SEAF, GOAR, GOAF, and FTAF overall. The cheeses of Coatepec and Perote showed higher intensities for the attributes CRTO, CIOD, ACID, CIAR, MILA, FITO, and FIMO, overall. These results showed that the cheeses from milk of grazing systems exhibited greater diversity of odors and aromas, which is consistent with the observations reported for Domiati cheese (6).

Table 3. Texture and color parameters for the fresh goat cheeses made in different dairies.

Parameter	Coacoatzintla	Coatepec	Perote	Tatatila
Hardness	8.81 ± 0.46[a]	45.58 ± 4.90[b]	48.42 ± 9.00[b]	8.33 ± 0.55[a]
Cohesiveness	10.31 ± 0.08[a]	12.79 ± 0.08[b]	10.64 ± 0.12[a]	10.46 ± 0.12[a]
Adhesiveness	−0.24 ± 0.17[b]	−1.15 ± 0.27[a]	−1.43 ± 0.61[a]	−0.67 ± 0.31[ab]
Gumminess	1.03 ± 0.20[a]	6.05 ± 0.60[b]	5.57 ± 1.10[b]	1.02 ± 0.30[a]
Chewiness	88.55 ± 3.59[a]	582.27 ± 65.20[b]	515.54 ± 99.00[b]	87.19 ± 6.65[a]
Elasticity	1.04 ± 0.09[a]	1.35 ± 0.27[b]	1.00 ± 0.00[a]	1.05 ± 0.06[a]
L*	89.57 ± 2.80[b]	93.70 ± 0.90[c]	82.75 ± 2.50[a]	85.06 ± 1.20[a]
a*	−1.33 ± 0.20[b]	−2.02 ± 0.10[a]	−0.74 ± 0.80[b]	−2.38 ± 0.40[a]
b*	9.99 ± 1.00[a]	11.23 ± 0.70[ab]	13.22 ± 2.60[b]	11.46 ± 1.20[ab]
C*	10.09 ± 1.70[a]	11.41 ± 0.20[ab]	13.27 ± 2.50[b]	11.70 ± 1.30[ab]
h°	82.30 ± 2.30[b]	79.81 ± 1.10[a]	85.62 ± 2.80[c]	78.34 ± 0.80[a]

[a, b, c]: Superscripts corresponding with homogeneous groups given by LSD Tukey test (P < 0.05).
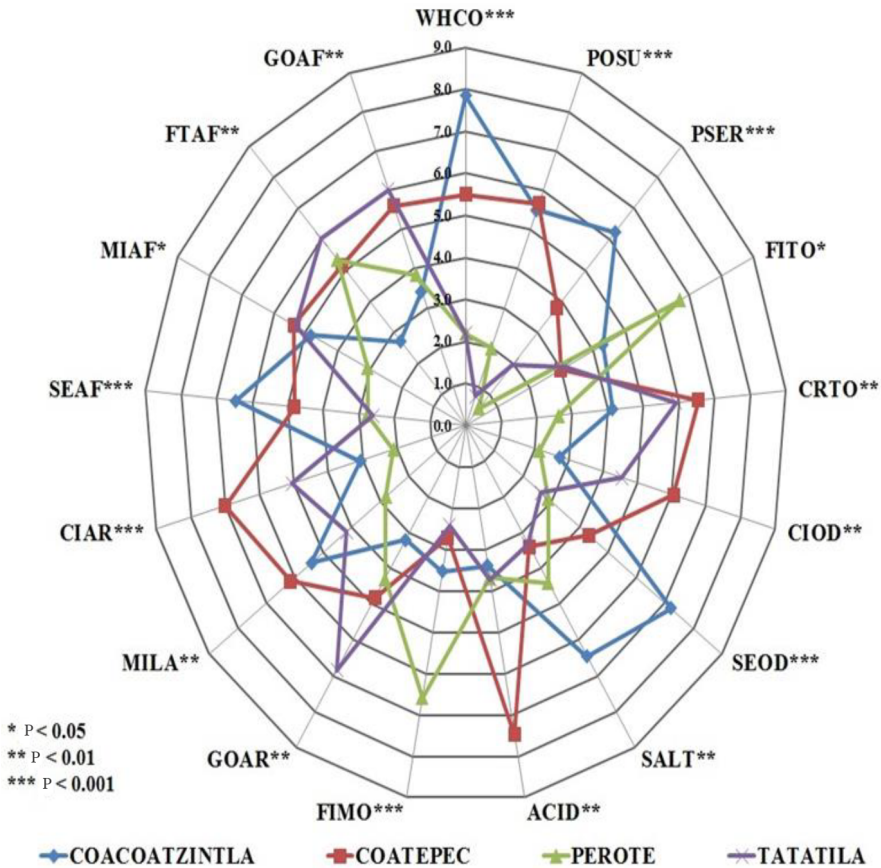
Figure 2. Sensory profile of fresh goat cheese of the central mountain area of the state of Veracruz, Mexico.

3.8. Consumer study

Four groups of consumers comprising 26, 11, 24, and 24 individuals were identified. The consumer factor showed no significant differences among cheeses; however, differences in the product factor (P < 0.05) were observed in assigning ratings. The cheeses of Tatatila were evaluated as 7.0 ("like moderately"), Coatepec 6.1, and Perote 6.0 ("I like slightly and moderately"). The cheeses of Coacoatzintla were qualified with an average of 4.3, placing them between "I dislike slightly" and "I am indifferent". The values were similar to those reported in other studies of fresh goat cheese (7).

3.9. Typification of the cheese by path models

The interpretation of path models is shown in Figures 3a and 3b. The CC, PS, MILC, CHC, INS, and SEN constructs presented discriminant validity because more than 50% of the variance was obtained from their own variables. The R^2 and β values meet minimum values between 0.1 and 0.3; therefore, the models have explanatory power (25). The goodness of fit (0.64 and 0.70) indicated a good fit of the models (8). The CC construct had a greater impact on PS (correlation = 0.64, β_{12} = 0.64 and correlation = 0.33, β_{12} = 0.33) than on MILC (correlation = 0.35, β_{13} = −0.79

and correlation = 0.16, β_{13} = 0.49), which was reported previously (26). The PS construct exhibited greater influence on the CHC construct (correlation = 0.81, β_{24} = 0.92 and correlation = 0.72, β_{24} = −0.23) compared to MILC-CHC route (correlation = 0.36, β_{34} = 0.49 and correlation = −0.99, β_{34} = −1.17). The CHC construct influenced the INS constructs (correlation = 0.71, β_{46} = 0.71 and correlation = −0.60, β_{46} = −0.60) and SEN (correlation = 0.86, β_{45} = 0.33 and correlation = 0.63, β_{45} = 1.14). The INS construct was associated with variables of the SEN construct (correlation = 0.97, β_{56} = 0.74 and correlation = 0.16, β_{56} = 0.85). The route among the INS-Consumers Class (correlation = −0.62, β_{67} = 2.65 and correlation = 0.96, β_{68} = 0.63; correlation = −0.73, β_{67} = −0.80 and correlation = 0.28, β_{68} = 0.12), respectively, and SEN-Consumers Class constructs (correlation = −0.78, β_{57} = −3.33 and correlation = 0.95, β_{58} = 0.33; correlation = 0.29, β_{57} = 0.42 and correlation = 0.97, β_{58} = 0.95) explained the preference. Model 1 (Figure 3a) showed that the PS-SST (0.93) with feed of Star grass and King grass (0.78) (Coacoatzintla) generated cheeses with high moisture (0.99), which influenced L* (0.99), elasticity (0.80), WHCO (0.81), POSU (0.80), PSER (0.84), CRTO
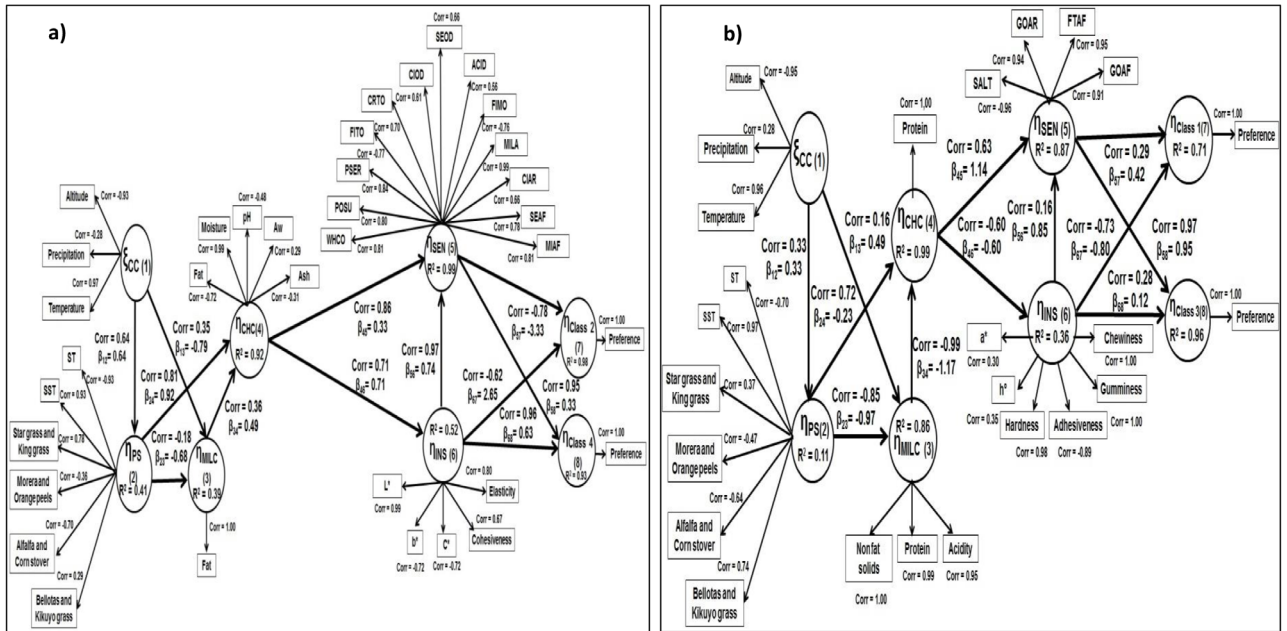
Figure 3. a) Typing model of fresh goat cheese for consumer classes 2 and 4 (main factor one MFA), b) typing model of fresh goat cheese for consumer classes 1 and 3 (main factor two MFA).

(0.70), MILA (0.99), SEAF (0.78), and MIAF (0.81). The preference of consumers of class four (β_{68} = 0.63 and β_{58} = 0.33) was explained by the INS (L* and elasticity) and SEN (WHCO, POSU, PSER, CRTO, MILA, SEAF, and MIAF) parameters. In the same model, PS-ST (–0.93) and feed with alfalfa and corn stover (–0.70) (Perote) generated cheeses with high contents of fat (–0.72), influencing FITO (–0.77), FIMO (–0.76), b* (–0.72), and C* (correlation = –0.72). The preference of class two was explained by texture parameters (correlation = –0.78, β_{57} = –3.33) and tonality (correlation = –0.62, β_{67} =2.65). The second model (Figure 3b) showed that PS-ST (Perote and Coatepec) with feed of alfalfa and corn stover (–0.64) and morera and orange peels (–0.47) (correlation = –0.60, β_{46} = –0.60) generated cheeses with high hardness, gumminess, and chewiness, which explains the preference of class three (correlation = 0.28, β_{68} = 0.12). It is also noted that PS-SST (Tatatila) (0.97) and feed based on bellotas and Kikuyo grass (0.74) generated cheeses with high protein content (1.00) and low

adhesiveness (–0.89), INS (correlation = –0.60, β_{46} = –0.60), and SEN attributes (correlation = 0.63, β_{45} = 1.14) GOAR (0.94), FTAF (0.95), and GOAF (0.91). The adhesiveness and sensory attributes explained the preference of class numbers one and three. The preference of consumers for cheeses with GOAR has been reported (7). With the information obtained through the perspective of typicity and the use of path modeling, it was possible to establish that the agroecological conditions and production systems influenced the characteristics of these cheeses. The cheeses preferred by consumers were obtained from semistabled systems and they were distinguished for being softer and adhesive with high brightness and slightly yellow, besides presenting greater intensity in the presence of serum, goat aroma, and fat aftertaste. The proposed methodology is expected to allow the handling of a large number of variables and parameters involved with typicity and to generate information for establishing the potential of cheeses associated with a specific territory.

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