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Chemical and Nutritional Composition of Tejate, a Traditional Maize and Cacao Beverage from the Central Valleys of Oaxaca, Mexico

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Abstract Foam-topped cacao and maize beverages have a long history in Mesoamerica. Tejate is such a beverage found primarily in the Zapotec region of the Central Valleys of Oaxaca, Mexico. Historically tejate has been ceremonially important but also as an essential staple, especially during periods of hard fieldwork. However, the nutritional contribution of traditional foods such as tejate has not been investigated. We analyzed tejate samples from three Central Valley communities, vendors in urban Oaxaca markets and one migrant vendor in California, USA for their proximate composition, amino acid content and scores, and mineral and methylxanthine content. Nutritional and chemical variation exists among tejate recipes, however, the beverage is a source of energy, fat, methylxanthines, K, Fe and other minerals although their availability due to presence of phytates remains to be determined. Tejate is a source of protein comparable to an equal serving size of tortillas, with protein quality similarly limited in both. Tejate provides the nutritional benefits of maize, and some additional ones, in a form appealing during hot periods of intense work, and year round because of its cultural significance. Its substitution by sodas and other high glycemic beverages may have negative nutritional, health and cultural consequences.

Keywords Dietary transition · Maize · Oaxaca, Mexico · Tejate · *Theobroma* spp · Traditional beverage

Introduction

Foam-topped beverages made with cacao, some containing maize, have a long history in Mesoamerica (for cacao fruit pulp [1] and for cacao bean [2]). In his Historia General de las Cosas de Nueva España, 1547–82, Sahagún [3] describes the preparation of beverages by grinding cacao beans alone, then grinding them together with cooked maize, after which a stream of water is introduced in order to create a foam-topped beverage. The tradition of making such beverages continues among contemporary peoples of Mesoamerica, with the production of abundant foam, and important and appreciated esthetic criterion [4, 5]. One such beverage that is based on maize and cacao is known as tejate in the Central Valleys of Oaxaca, Mexico [6, 7].

Tejate—or similar beverages with different names—is found primarily in the Zapotec region of the Central Valleys of Oaxaca. Historically tejate has been an important ceremonial beverage but also an essential food in the Central Valleys, especially during periods of hard fieldwork. Many people see tejate as a required food during the maize harvest, and it is also associated with some festivities such as those surrounding Easter week. Tejate continues to be a valued traditional food even among many non-rural

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households who never prepare it. In urban and peri-urban areas of the Central Valleys tejateras (women who prepare tejate for commercial sale) make large quantities of tejate daily that they sell in markets and on the street. The demand for tejate in migrant communities from the Central Valleys living in the US has led some women to import ingredients and make and sell tejate from their homes in the US [6].

Tejate preparation is labor-intensive [6], including nixtamalization by cooking maize grains in ash water then grinding them into a smooth masa or dough. Other ingredients are individually toasted and ground into a separate masa of pixtle (*and elsewhere*); seeds of *Theobroma cacao*, *T. bicolor*, mamey (*Pouteria sapota*), and blossoms known as rosita de cacao (*Quararibea funebris* (La Lalve) Vischer (Bombacea)). The two masas are combined and ground together. Then, water is poured from a height is added as they are whipped by hand into a milky, foam-topped liquid (Fig. 1).

The "nutritional transition" from traditional to industrially manufactured foods, and the accompanying decrease in physical activity and increase in nutrition-related noncommunicable chronic diseases [8] is underway in Mexico, including Oaxaca. Today, tejate is no longer made in some communities and households that prepared it in the past. A 2007 survey of 25 households in each of three rural Central Valley communities found that over 88% of households made tejate several times/week in a more traditional Zapotec community, while only 7% prepared it in a predominantly Mestizo community (Soleri field notes). The level of tejate consumption in some rural Oaxacan communities suggest that it could be a significant dietary contribution currently, and may have been even more important and widespread in the past. Thus, despite some loss of traditional foods like tejate, many Oaxacan households highly value traditional foods, especially prepared with local varieties of maize and other regional ingredients [e.g., 9, 10]. However, there is little scientific research quantifying the characteristics and potential nutritional contributions of many traditional foods.

Fig. 1 Water is poured from a height to begin mixing and then frothing tejate (Photo DA Cleveland)

There are no published data concerning the nutritional and chemical characteristics of tejate. In some other important regions of Mexico, traditional maize-based beverages have been investigated and found to make valuable contributions, especially to the diets of poorer households [11, 12]. To better understand the contribution of tejate to the diets in the Central Valleys of Oaxaca, this study investigated its chemical and nutritional characteristics, using samples including tejate prepared for home consumption and market sale, and using different varieties of local maize and traditional recipe variants. We quantified the proximate composition (water content, ashes, fat, protein, crude fiber, carbohydrates), the presence of the stimulants theobromine and caffeine, total energy content, concentrations of the minerals Fe, K, Zn, Ca and Mg, and amino acid content and scores of tejate.

Materials and Methods

Study Sites and Samples

There is anecdotal evidence that tejate preparation today is limited to two of the three Central Valleys of the high elevation plateau where the city of Oaxaca is located [7]. Three of our study sites (San Bartolomé Quialana [n=25], Teotitlán del Valle [n=25], Villa Díaz Ordaz [n=1]) lie in the Mitla Valley, the other, Trinidad Zaachila (n=27), in the Zimatlan Valley. All are Zapotec farming communities within a 1.5 h bus ride of the state capital with populations between 4,400 and 800 in 2005 [13]. Through labor migration, commerce and/or tourism all these communities are partially integrated into the urban economy of the capital city. As part of a larger study of tejate (Soleri field notes), random samples of 25 households in each community were identified using local health clinics' complete census (the exception was Villa Díaz Ordaz where only one household was sampled based on a previous contact with the researchers). All 25 households were interviewed, whether or not they prepare tejate. Among those households who prepared the beverage, one fresh tejate sample was obtained from each of a small number of households in each community. Single samples were obtained from three tejateras in markets in Oaxaca City. One sample was also included from a tejatera originally from San Bartolomé Quialana and currently living in greater Los Angeles, CA, USA who sells masa of tejate from her home to other migrants from the Central Valleys. Descriptions of samples analyzed in this study are given in Table 1. Samples were immediately frozen, packed in insulated containers and express shipped to Dr. Sotelo's laboratory at UNAM in Mexico City. For most of the data reported here three subsamples of tejate were taken from each field sample that was collected to allow triplicate analyses of each sample.

Table 1 Tejate samples included in this study

Sample	Sample wt (g)	Maize[a]	Other ingredients
San Bartolomé Quialana			
A-04	352.1	Yellow	Pixtle, peanuts, cacao, rosita de cacao, sugar
A-14	478.4	White and yellow	Pixtle, cacao, rosita de cacao
A-18	461.0	White	Pixtle, cacao, rosita de cacao, sugar
A-23	342.7	White and yellow	Pixtle, cacao, rosita de cacao, sugar
Trinidad Zaachila			
B-06	474.9	White	Pixtle, cacao, cacao blanco, rosita de cacao, sugar
B-23	358.2	White	Pixtle, cacao, cacao blanco, rosita de cacao, coconut, sugar
B-26	465.5	White	Pixtle, cacao, cacao blanco, coconut, rosita de cacao, sugar
B-27	324.1	White and yellow	Pixtle, cacao, cacao blanco, rosita de cacao, sugar
Teotitlán del Valle			
C-08	221.3	Yellow	Cacao, rosita de cacao, sugar
C-21	392.3	White and yellow	Cacao, rosita de cacao, sugar
Villa Díaz Ordaz			
D-01	503.8	Yellow	Cacao, rosita de cacao, sugar
Oaxaca City markets			
T-01	.	White	Pixtle, cacao, rosita de cacao, sugar
T-02	481.9	White	Pixtle, cacao, walnuts, rosita de cacao, sugar
T-03	354.0	White	Pixtle, cacao, rosita de cacao, sugar
Los Angeles, CA, USA, tejatera originally from San Bartolomé Quialana			
USA-1	202.7	White, industrial variety (bird feed)	Pixtle, cacao, rosita de cacao

[a] Local farmer variety unless otherwise indicated

. No data

Chemical Analyses

The proximate composition of tejate samples was determined according to the methods described in AOAC [14]. Wende's scheme was followed: moisture, crude protein (N×6.25), ash, crude fiber, crude fat and protein free extract. Energy content was measured using a ballistic calorimetric pump (Gallenkamp) using a calibration curve of certified benzoic acid; results were expressed in both kcal and kJ/100 g dw (dry weight). Carbohydrate content was calculated on dry weight basis as followed: $100 - (\textit{protein content} + \textit{ashes} + \textit{fat} + \textit{fiber})$. For energy content, 16.75 kJ/g of protein or carbohydrate and 37.68 kJ/g of fat were used. Theobromine, theophylline and caffeine were quantified using the method 980.14 described in AOAC for cacao products [14: Vol II].

The following experimental conditions were used: HPLC chromatographic system, Waters 2695 with dual UV/visible (λ=280 nm) detector. Column: Waters Spherisorb 5 μm ODS2, 4.6×150 mm. Mobile phase. Water:acetic acid:methanol (74:1:25). Flux velocity: 1 ml/min. Caffeine, theobromine and theophylline standards from Sigma (St. Louis, MO). Standard concentrations were prepared from a stock solution of 500 μg of methylxanthine/mL mobile phase. Theobromine standard curve was prepared 5 to 50 μg/mL, while that of caffeine was 0.25 to 4 μg/mL. Theophylline was not quantified, as it was found in concentrations lower than the detection and quantification limits. Results were expressed in g/100 g dw. Concentrations of K, Ca, Mg, and Zn were determined by atomic absorption spectrometry using a Varian Specter AA 220 (Varian, Santa Clara, CA) after acid hydrolysis, while Fe concentration was measured following the AOAC method using orthophenanthroline (944.02).

Amino acid determination was carried out after acid hydrolysis with 6 N HCl for 4 h at 145 °C by HPLC, using the technique described by Bidlingmeyer et al. [15] and Cohen & Michaud [16], after the derivatization with 6-aminoquinolyl-N-hidroxisuccinimidilcarbamate. Tryptophan was measured after alkaline hydrolysis with 4 N LiOH for 4 h at 100 °C [17] by HPLC according to Yust et al. [18]. The amino acid profile was measured using an Alliance HPLC Bioseparations System chromatograph (Waters Corp., Milford, MA), using an AccQ Tag Nova-Pak C18 3.9 mm×150 mm column (Waters Corp., Milford, MA).

Statistical Analyses

All chemical analyses for each sample were determined for triplicate subsamples except Fe content whose results are from quadruplicate subsamples. Statistical differences between samples were tested with the Tukey's means separation test using SAS 9.2 software [19].

Results

Proximate Composition and Energy Content

Proximate composition of tejate samples is given in Table 2. Water content varied between 54.6 (sample USA-1, tejate masa) to 94.9%; protein from 7.0 to 13.7 g/100 g DW; fat 2.8–20.2 g/100 g, ash 1.2–3.1 g/100 g DW. Fiber (0.7–1.9 g/100 g) and fat content showed the greatest variation among samples; carbohydrate and then energy showed the least variation. More research is necessary to determine whether the lowest fiber content (USA-1) is related to that being the only tejate prepared using maize that is not a local Oaxacan landrace (maíz criollo) from the Central Valleys; Mexican maize landrace grain quality can differ substantially from industrial hybrids [20]. Average carbohydrate concentrations and energy values were 79.2 g and 2147 kJ (513 kcal)/100 g DW, respectively. Variation in composition among samples is likely due to different recipes and amounts of ingredients used to prepare the beverage. At the community level, samples from Trinidad Zaachila have higher fat and lower carbohydrate content in g/100 g DW than the other community samples. As a group, the samples from Oaxaca tejateras were also high in fat and energy (Table 2).

Methylxanthines

Methylxanthine derivatives (theobromine, caffeine and theophylline) are present in cacao and products made from it [21]. The concentration of these stimulants depends on a variety of factors, including cacao processing procedures, genotype, geographical origin and bean weight [22].

The detection of two methylxanthine compounds (caffeine and theobromine) in the samples indicates the presence of cacao (electronic supplementary material [ESM]1). Caffeine and theobromine were detected in all samples, although sample B-23 had caffeine content below the detectable limit in this study. However, methylxanthine concentration is not directly correlated with fat content in the samples, indicating that fat sources other than *Theobroma* spp. were present and especially abundant in the high-fat, low-methylxanthine samples B-23 and B-26, both of which contained coconut. Tejatera sample T-02 had high values of methylxanthines and was very high in fat content from both *T. cacao* and the addition of walnuts to her masa of pixtle. The highest methylxanthine concentration was present in tejatera sample T-03; the low fat content of this sample suggests no additional source of fat aside from typical ingredients of masa de pixtle (cacao rojo, pixtle, rosita de cacao). Recipes containing cacao blanco—all samples from Trinidad Zaachila—as a group had the highest fat content but significantly lower methylxanthine concentrations than any other group. This is consistent with the finding that *T. cacao* contains concentrations of those compounds 18 times higher than *T. bicolor*, but only slightly more fat (24 v. 17%, respectively) [23]. Variations in methylxanthine levels in tejate samples are also likely a consequence of different individual recipes as well as different varieties and qualities of *T. cacao* [22].

Minerals

Selected tejate samples were analyzed for mineral content. In these samples tejate was found to be especially rich in K, consistent with the particularly high levels present in ash-nixtamalized maize, and supported by the higher K content in the high ash samples (see Table 2) for which mineral content was analyzed (A-04, C-21, A-18) (Table 3), though there are insufficient data to test the hypothesis of a correlation. Tejate is also a good source of Fe, Zn, Ca and Mg, all of which are important micronutrients. However, because these minerals are often bound to phytates, their availability must be determined to establish whether or not they are making a nutritional contribution to tejate consumers, although other traditional foods in the diet may reduce phytate content [24]. Nevertheless, as shown in other cereals, when maize is the primary source of energy can also be the main source of some minerals in the diet, as well as other nutrients (Table 4). This was found to be the case for children in Benin where maize provides 2.6 mg/100 g Fe and 2.2 mg/100 g Zn, dry weight basis [25].

Amino Acids

Amino acid content of four samples from this study is reported in ESM2, while amino acid scores [26] are given in ESM3. In all cases the only amino acids that are not consistently limiting are histidine and tryptophan as is for maize tortillas (see ESM3). In some cases tejate samples had higher amino acid scores for individual amino acids or groups than was for maize tortillas, but this was highly variable. The amino acid scores of these samples (between 0.44 and 0.49) reflect these deficiencies and indicate that tejate alone and in moderate quantities is not a high quality source of protein, as is maize itself. For example, the amino acid score of maize tortillas is approximately 0.52 (calculated from [27]).

Discussion

Tejate is one component of the maize-centered dietary traditions of the Central Valleys of Oaxaca, Mexico. It has traditionally been consumed year round, and is especially known as an essential accompaniment to periods of intense agricultural labor that fall during the hot summer and autumn months in the region's rain fed farming systems. During this time, it appears that many households

Table 2 Proximate composition and energy content for 100 g dry weight (dw) of individual tejate samples, and by community or group[a,b]

Sample, community and group	Moisture content,%		g/100 g dw										Energy/100 g dw			
			Protein[c]		Fat		Ash		Fiber		Carbohydrates[d]		kJ		kcal	
	Ave	StD	Ave	StD	Ave	StD	Ave	StD	Ave	StD	Ave	StD	Ave	StD	Ave	StD
San Bartolomé Quialana	81.16b	1.82	10.94a	1.32	4.70b	0.46	1.91b	0.21	0.44a	0.36	81.21ab	0.93	2013.7ab	89.6	485.6ab	21.4
A-04	83.02	0.57	11.90bc	0.20	4.16i	0.17	2.22d	0.01	0.18d	0.01	80.66ef	0.30	1999.1c	12.4	477.8c	3.0
A-14	82.50	0.21	9.49g	0.04	4.76gh	0.06	1.84ef	0.03	0.27d	0.02	82.45c	0.56	1989.9c	106.1	475.6c	25.4
A-18	80.31	0.76	9.92fg	0.16	5.33fg	0.06	1.92e	0.03	0.28d	0.02	81.41de	0.22	1999.2c	82.2	477.8c	19.6
A-23	78.80	0.15	12.43b	0.40	4.52hi	0.18	1.67g	0.03	1.04c	0.05	80.34f	0.59	2138.6bc	55.6	511.1bc	13.3
Trinidad Zaachila	87.14a	1.50	8.31a	1.47	12.66a	3.05	1.43b	0.23	1.10a	0.63	75.58b	3.55	2239.5ab	153.1	535.3ab	36.6
B-06	87.98	0.72	6.97j	0.38	10.35d	0.30	1.30i	0.02	1.09bc	0.03	78.46h	0.25	2217.9bc	101.5	530.1bc	24.3
B-23	85.68	0.71	7.47ij	0.30	16.12b	0.41	1.21i	0.01	1.29bc	0.13	73.56j	0.54	2453.0ab	105.6	586.3ab	25.2
B-26	88.93	0.37	10.58de	0.11	14.90c	0.23	1.79f	0.02	0.18d	0.01	71.09k	0.20	2120.2bc	71.8	506.7bc	17.2
B-27	85.97	0.12	8.21h	0.32	9.26e	0.06	1.42h	0.05	1.84a	0.18	79.22gh	0.09	2167.0bc	62.7	517.9bc	15.0
Teotitlán del Valle	86.85a	3.02	11.11a	0.35	4.11b	0.14	2.70a	0.43	0.78a	0.71	80.73ab	0.75	2097.8ab	54.9	501.4ab	13.1
C-08	89.53	0.81	11.43c	0.07	4.18i	0.09	3.09a	0.09	0.13d	0.01	80.07fg	0.08	2060.2c	23. 6	492.4c	5.6
C-21	84.16	0.66	10.79d	0.02	4.05i	0.18	2.31cd	0.03	1.42b	0.15	81.39de	0.31	2123.0bc	58.3	507.4bc	13.9
Villa Díaz Ordaz	85.76ab	0.31	10.33a	0.08	2.82b	0.13	1.54b	0.02	0.16a	0.01	84.18a	0.09	1989.0b	123.4	475.4b	29.5
D-01	85.76	0.31	10.33def	0.08	2.82j	0.13	1.54h	0.02	0.16d	0.01	84.18b	0.09	1989.0c	123.4	475.4c	29.5
Oaxaca tejateras	90.13a	4.47	10.66a	3.30	11.70a	6.63	1.52b	0.67	0.42a	0.49	77.51ab	8.36	2320.7a	342.1	554.7a	81.8
T-01	84.67	0.16	.	.	9.50e	0.12	1.24i	0.07	1.06c	0.05	87.27a	0.16	.	.	.	.
T-02	94.85	0.81	7.64hi	0.05	20.21a	0.13	2.72b	0.02	0.07d	0.01	67.96	0.43	2572.4a	313.2	614.8a	74.9
T-03	90.87	0.34	13.67a	0.07	5.39f	0.24	2.35c	0.04	0.12d	0.01	77.29i	0.20	2069.0c	66.8	494.5c	16.0
US tejatera	54.60c	0.19	10.08a	0.04	5.44b	0.11	1.52b	0.04	0.25a	0.34	82.29ab	0.23	2137.6ab	58.2	510.9ab	13.9
USA-1	54.60[e]	0.19	10.08efg	0.04	5.44f	0.11	1.52b	0.04	0.25d	0.34	82.29cd	0.23	2137.6bc	58.2	510.9bc	13.9
Overall, average, StD	83.84	8.88	10.07	1.93	8.07	5.14	1.88	0.55	0.63	0.59	79.18	4.91	2147.5	194. 4	513.3	46.5
CV		0.11		0.19		0.64		0.29		0.94		0.06		0. 1		0. 1

[a] Average, standard deviation (StD) of triplicate subsamples taken from single field samples listed in Table 1

[b] In columns, averages followed by different letters are significantly different, Tukey's means separation, $p<0.05$. Letters following community or group average indicate means separations among those groupings only, not individual averages

[c] Calculated as (N×6.25) according to [14:Vol I]

[d] Calculated by difference, $n=2$ subsamples/numbered field sample

[e] Low water content because sample was of tejate masa not mixed tejate beverage

. No data

Table 3 Mineral composition of selected tejate samples[a], maize, and maize samples nixtamalized with ashes or lime, fresh weight mg/100 g

Sample	% moisture	Fe[b]		K		Zn		Ca		Mg	
		Ave	St Dev	Ave	St Dev	Ave	St Dev	Ave	St Dev	Ave	St Dev
A-04	83.0	1.47b	0.03	71.24a	3.77	0.72a	0.03	8.20b	1.17	23.10ab	1.97
A-18	82.3	2.10a	0.04	65.09a	13.17	0.68a	0.16	10.95a	3.83	26.16a	8.79
B-06	88.0	0.42d	0.02	33.66c	1.62	0.25d	0.02	4.67d	0.29	10.70d	0.81
B-26	88.9	0.26e	0.01	40.16bc	2.86	0.39c	0.02	4.64d	0.18	14.91cd	1.35
C-21	84.2	.	.	70.72a	3.05	0.41c	0.02	5.02cd	0.42	17.76bc	0.91
D-01	85.8	0.55c	0.04	43.09b	3.82	0.52b	0.02	7.85bc	0.53	16.54cd	0.92
Uncooked maize[c]	11.5	3.32	0.06	269.87	31.93	3.65	1.52	16.86	4.70	91.93	20.89
Lime processed masa[c]	59.9	4.96	0.23	378.70	1.59	7.10	0.07	92.43	2.86	194.89	9.80
Ash processed masa[c]	64.0	8.83	0.34	423.78	0.15	9.58	0.33	72.99	3.91	212.95	1.90

[a] In columns, averages of tejate samples followed by different letters are significantly different, Tukey's means separation, $p<0.05$

[b] Colorimetric method [14]

[c] [28]

. No data

consume(ed) the majority of their maize, and thus energy and several nutrients, in the form of tejate. This beverage likely played a special role in local diets either replacing or complementing the nutritional contributions of other maize foods and their accompaniments. As a cool liquid, tejate is a source of the nutritional benefits of maize in a form suited to the hot season, providing hydration and replacing other foods including tlayudas (large, dry local tortillas) that can be less appealing under those circumstances. Indeed, in the quantities typically consumed, the protein and energy contributions of tejate can be comparable to that of maize tortillas (see Table 4).

Table 4 Comparison of servings of tejate and other beverages, and maize tortillas, 237 ml[a] serving unless otherwise noted[b]

Beverage or food	Energy		g			mg						
	kJ	kcal	Fat	Carbohydrate	Protein	Caffeine	Theobromine	Ca	Fe	Mg	K	Zn
Tejate, San Bartolomé Quialana, ave	497	120	1.16	20.05	2.70	2	17	26	4.56	66	186	1.90
Tejate, Trinidad Zaachila, ave	720	172	4.07	24.30	2.67	1	5	13	0.94	36	103	0.90
Tejate, Teotitlán del Valle, ave	690	165	1.35	26.55	3.65	1	13	10	.	37	147	0.84
Tejate, Oaxaca tejateras, ave	573	137	2.89	19.13	2.63	3	23	.	.	.	.	.
Simple atole, Michoacán[c,d]	1037	248	0.16	11.94	1.13	.	.	.	.	.	.	.
Chorote[e,f]	.	.	6.25	.	17.48	.	.	.	.	.	.	.
Hot chocolate, Mexican (39.5 g in 237 ml water)[d,g]	898	215	13.15	21.96	2.80	79	474	15	0.95	40	.	.
Cocoa beverage mix, powder, prepared with water[h]	632	151	152.00	1.52	31.68	8	120	56	0.48	32	272	0.56
Soda[h]	385	92	0.60	23.47	0.17	20	0	6	0.28	1	6	0.05
Coffee[h]	6	1	0.04	0.00	0.29	95	0	4	0.02	7	115	0.05
Orange juice drink[h]	567	136	0.00	33.40	0.50	0	0	5	0.27	7	105	0.05
Pineapple juice, unsweetened[h]	550	131	0.30	32.17	0.90	0	0	32	0.78	30	325	0.28
Tortilla, ~100 g serving[d]	811	194	1.00	43.00	4.50	0	0	177	1.40	65	192	1.40
Tortilla, 4 count ~100 g[h]	912	218	2.85	44.64	5.70	0	0	81	1.23	72	186	1.31

[a] Equivalent to 8 oz or 1 c

[b] Sample sizes for tejate data: San Bartolomé Quialana $n=4$, except minerals, $n=2$; Trinidad Zaachila $n=4$, except minerals, $n=2$; Teotitlán del Valle $n=2$, except minerals, $n=1$; Oaxaca tejateras $n=3$, except methylxanthines $n=2$

[c] A warm beverage of lime nixtamalized, ground maize

[d] [36]

[e] A cool beverage of lime nixtamalized maize and *T cacao* that are ground, fermented and mixed with water

[f] [37]

[g] Methylxanthine values, unpublished data from Dr. Sotelo's laboratory, UNAM

[h] [27]

Additionally, dietary contributions of tejate will depend on what it might offer in addition or complementary to the rest of the diet, either based on its preparation or other ingredients in this traditional beverage. Tejate is distinct because maize is nixtamalized with ashes, instead of lime ("cal", calcium hydroxide [$Ca(OH)_2$]) as is the case for most local maize foods. These forms of processing appear to have different outcomes in terms of mineral content of the resulting masa. A study comparing the properties of maize treated with lime v. wood ash found that ash-nixtamalized maize contains 14.4 times the level of Fe of the lime (treated), 15.0 times the level of Zn, twice as much of Mg and 8.4 times of K [28]. Thus, based on its preparation, tejate can be a relatively mineral-rich maize food.

Pixtle and rosita de cacao are ingredients used exclusively in the preparation of tejate; *T. cacao* and *T. bicolor* are used in other beverages and foods, though far less for the latter. The potential contributions of pixtle and rosita de cacao remain to be investigated, but both *T. cacao* and *T. bicolor* are sources of fat, energy, polyphenols (plant derived compounds with antioxidant activity; their concentration and availability still under investigation [29, 30]) and methylxanthines [21–23]. As such, depending on the recipe, tejate may be one of the few midday sources of the stimulants caffeine and theobromine in the traditional diet of the area, and may contribute to the benefits offered by dietary polyphenols.

Our analyses also provide evidence of differences in interpretation of this traditional recipe across geographical locations, and among different procedures. The recipes reported here (Table 1) reflect the findings of the larger survey work that documented cacao blanco used in making tejate by 29, 82, and 0% of households and pixtle used by 88, 100, and 4% of households in San Bartolomé Quialana, Trinidad Zaachila and Teotitlán del Valle, respectively. Methylxanthine content (dry weight) was particularly high in samples from tejateras, indicating recipes with greater proportion of *T. cacao* to maize than home prepared tejates (ESM1). Thus, variation among individual preparations was often as great as it was between locations or types of procedures.

Tejate's role in the lives of many Central Valley Zapotec communities appears to be changing from a homemade beverage consumed daily, to a less frequently consumed drink that is often market-purchased [6, 7]. This change is part of the "nutritional transition" in Oaxaca. In our research, 95% of the interviewed households stated that their parents consumed tejate more frequently than they do today; 58% of households reported the consumption of soda ("refrescos"; sweetened, carbonated beverages) instead tejate; as many as 71% of households in one community. Indeed, households in one community reported that the local health clinic was advising residents not to drink tejate because it was "fattening" and may be contributing to diabetes among residents. Yet, when tejate is replaced by beverages such as soda that may appear "lighter", consumers may in fact be consuming more calories, especially in the form of simple carbohydrates, and not receiving the nutritional benefits of tejate (see Table 4). Another benefit that may be lost by this substitution is the satiety relative to high energy, high glycemic index beverages such as sodas or even fruit-flavored, sweetened waters (aguas frescas, substituted by 51% of households). There is some evidence that the lack of satiety associated with those substitutes may contribute to increased calorie consumption and obesity [for references see 31]. A review of dietary, health and household expenditure data between 1980 and 1998 in Mexico found rising standardized mortality rates, including sharp increases in noncommunicable chronic diseases like type 2 diabetes mellitus, and a 78% increase in the occurrence of overweight and obesity [32]. These changes have been observed in both urban and rural Mexican populations [8]. Over the same period household expenditures on soda increased 27%, even while spending on other food groups remained the same or declined slightly. The authors of that study lack sufficient data to determine whether a causal relationship exists between these two trends, especially because other variables such as changes in physical activity were not documented. However, a recent study in Mexico found statistically significant associations between soda consumption and overweight, obesity and excess body fat [31]; another study found 61% Mexican households consuming sodas, the largest single source of calories among all energy-containing beverages across all age groups in the country [33]; nearly 17 billion liters consumed in 2008, over 158 liters person^{-1} [34].

Increasingly nutritional, medical and public health scientists warn of the perils of the nutritional transition, including the loss of traditional foods that often have positive health attributes and substantial cultural significance [8, 35]. Investigation of the chemical and nutritional characteristics of foods such as tejate can provide information for local health workers in their efforts to help individuals and communities retain or regain their physical well being and cultural identities. We hope that this tejate study may contribute in that way to the Oaxacan communities who have maintained this unique, traditional beverage for generations.

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