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Effect of Different Corn Processing Techniques in the Nutritional Composition of Nixtamalized Corn Tortillas

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Abstract

Maize in the form of tortilla plays an important role in the diet of Mexican population, with a per cápita consumption of 157 g/day. The two main methods for tortilla are the traditional method, which uses maize dough or masa made in the ancient manner; and the industrial method, which uses industrially-processed maize flour. Both methods are based on the alkaline-processing of maize known as nixtamalization. Chemical profiles of maize tortillas were analyzed. Samples were collected between 2012 and 2013 in three lots, one every six months, from four retail shops at 16 municipalities of Mexico City; tortillas made of maize flour were obtained from two supermarkets of four municipalities. Composition changed according to raw materials and production method. Samples made with nixtamal dough showed lower contents of moisture, of about 5%, and absence of thiamine and riboflavin than nixtamal flour. Differences in carbohydrates and iron, 0.5% more in case of iron, may be caused by maize phenotype; while differences in crude fat 1% more, dietary fiber 0.5% more, thiamine, and riboflavin are due to additives added by manufacturers; however, concentration of vitamins and minerals in the final product were below theoretical values. In case of calcium, 100% more in maize dough tortillas is due to lime amount added on each method or amount of broken grain processed. Regarding on effect of sampling, contents of protein and crude fat remained constant on dough tortillas regardless of sample collection and these were consistently higher than maize flour tortillas over time, 0.3% and 1%, respectively, which is due to maize phenotype. On flour-made tortillas, fat and dietary fibers were also constant since maize flour manufacturers add additives and nutrients to obtain certain rheological characteristics and nutritional content on maize flour tortillas.

Keywords: Maize; Nixtamal; Tortilla; Nixtamal flour; Nixtamal dough; Chemical composition

Abbreviations:

MD: Maize Dough Tortillas; MF: Maize Flour Tortillas; MD/MF: Maize Dough and Flour Tortillas; TM: Traditional Method; IM: Industrial Method; OMS: Official Mexican Standard; TS: Tortilla Shop

Introduction

Maize tortillas play an important role in diet of Mexicans, with a per capita consumption of 157 g/day [1]. Tortilla industry comprises nixtamal mills, Tortilla Shops (TS) (a shop that produces and sells tortillas), and nixtamal flour factories, which represent the main form in which maize is industrially processed in Mexico.

The methods for tortilla production based on the alkaline-processing known as nixtamalization are: Traditional Method (TM), which uses Maize Dough (MD) and Industrial Method (IM), which uses industrially-processed Maize Flour (MF).

Nixtamalization produces changes in maize such as easy pericarp removal [2], partial gelatinization of starches [3], protein solubility [4], and niacin release [5]. Furthermore, lime increase calcium content of tortilla, up to 400% as compared to unprocessed maize [3].

The nixtamalization has been previously studied, and information is available on effects of: different cooking times and temperatures, lime concentration, number of rinsing after cooking and extra soaking before cooking. The differences on the former variables affect quality of tortillas [3-10].

The Official Mexican Standard (OMS) NOM-187 [11] establishes sanitary and commercial specifications for tortillas and other nixtamal-derived products. Other OMS such as NMX-FF-034 [12] and NMX-F-046 [13] define specifications for white maize to be used in production of MD, and those for MF, respectively. However, there is still no an OMS that establishes chemical specifications for tortillas.

Given the above, the aim of this study was to systematically evaluate nutritional composition of tortillas obtained by TM and IM obtained from nixtamal corn dough and using pre-processed flour, respectively. A second purpose was to evaluate variability of composition among tortillas by raw material and point of sale, as well as variability of sampling on same groups.

Material and Methods

Collection of samples

Tortillas were obtained between 2012 and 2013, from the 16 municipalities of Mexico City. Four TS were selected randomly from each municipality, and batches of 2 kg were bought. At the same time, two supermarkets that produce their own tortillas were selected in four municipalities and 2 kg were obtained at each point of sale. In these same stores, pre-packed tortillas produced in a factory elsewhere were also purchased. All kinds were collected three times, once every six months.

Sample treatment

Moisture (AOAC 925.09) was determined on freshly samples; then were dehydrated at 67°C/14 h in an Apex Ltd. drier and grounded in a Thomas Wiley knife mill, with a 1 mm mesh.

Storage of samples

Dehydrated ground tortilla was divided into four 200 g aliquots. Two were analyzed and two were stored in hermetic plastic containers and then into boxes at room temperature (23 ± 2°C).

Analytical methods

Proximate composition, vitamins and minerals were analyzed by duplicate according to the AOAC techniques: moisture (925.09), nitrogen (977.14) using a 6.25 factor to obtain content of crude protein, fat (920.39 and 963.15), ash (923.03) and total dietary fiber (985.29) [14].

Energy content was calculated according to OMS NOM-184 appendix C, clause 1 [15] which are based on At-water factors.

Ca, Fe and Zn were analyzed with an AOAC atomic adsorption-spectrophotometric techniques: 977.29, 944.02 and 986.15, respectively. While, thiamine and riboflavin with AOAC spectroscopy-fluorometric techniques: 924.23 and 970.65 [14].

Statistical analysis

Nutrients and confidence interval at 95% are reported by mean ± SD per 100 g of fresh weight. Descriptive statistic was calculated as described in Table 1; significances by point of sale and raw material were determined by Kruskal-Wallis, followed by U of Mann-Whitney tests, and differences among collections were determined by Friedman test. All statistical evaluations were carried out with SPSS v12.0 System.

To determine the similarity in chemical composition between the groups a cluster analysis was performed.

Groups	Description
Point of sale	Tortilla shop
	Supermarkets
Raw material	Maize Flour (MF)
	Maize Dough (MD)
	Maize Flour/Maize Dough mix (MF/MD)

Table 1: Description of the study groups.

Results and Discussion

At TS was common to mix MF with MD to make tortillas. Therefore, such mix was considered as another raw material (Table 1). 192 samples were obtained from TS, 24 from supermarkets and 45 samples were commercially-branded fully industrialized tortillas.

Chemical composition of tortillas by raw material and point of sale

Proximate composition, minerals and vitamins in tortillas are shown in Tables 2 and 3. MF tortillas had consistently the highest moisture as compared to MD; this difference agrees with other reports that mention a 5 g/100 g difference in moisture [6] due to addition of CMC, gums or unsaturated fatty acids to retain water [7,16]. Other authors consider that this difference is caused by MF processing conditions, which results in higher gelatinization-index and higher water-holding capacity [5].

Protein Content (PC) varies between MD and MF tortillas. It is known that MF industry prefers hard endosperm maize, as opposed to TM that favours white landraces [17]. Previous studies report PC, on dry basis, for MD tortillas of 7.58-15.63 g/100 g [10,18-21]. These reports have different maize descriptions, suggesting phenotypes were different; but also is known PC varies according to endosperm hardness [17]. However, on dry basis, results between MD and MF, were similar ($p>0.05$) and differences, per 100 g of fresh weight, are due to losses that take place during cooking, pericarp removal and wet milling of nixtamal in TM [5,21].

Energy Content (EC) of tortillas correlated with moisture with a coefficient r=-0.997. MD tortillas and MD/MF did not show difference; while MF tortillas had significantly lower EC due to their higher moisture levels.

Crude Fat (CF) contents show differences by raw material or point of sale, Table 2; this may be due to maize germ losses, which has up to 90% of lipids. Germ losses can reach 30% during nixtamalization and 17% during TM nixtamal rinsing [7]. The industry prefers high endosperm maize varieties, which results in low maize germ, but also in lower protein quality [6]. Maize phenotype may also affect fat content; however, it is noteworthy that MF sometimes is added with non-polar fatty acids that work as softeners at a concentration of approximately 1% [22,23]. Such fatty acids affect the content of crude fat in the final product.

Ash contents were different ($p<0.05$) by raw material and point of sale, Tables 2 and 3. These may be due to different extent of lime removal on TM because around of 0.5% differences were reported between MD tortillas made on different maize varieties that were soaked for 12-16 h in a solution of lime 0.6-2% g/kg of grain [10,19-21]; although, some authors report that differences are due to pericarp removal [24], suggesting there is no direct relationship between amount of lime used in the process and ash content.

Dietary Fiber (DF) was lower in MF tortillas ($p<0.05$) as compared to MD and the mix (Table 2); which may be due to: 1) Differences in soaking time and cooking temperature, since soluble carbohydrates increase as a function of these variables [25], 2) Partial or null pericarp removal, which increase insoluble fibrous elements of cell wall [26]. A pericarp excess affects colour of tortillas, possibly because of that, MF tortillas were whiter than MD tortillas; 3) Presence of resistant starch which is related to a harder endosperm and requires longer cooking times to let water enter the grain and solubilize starch [3]; tortilla producers are not able to control this and do not adjust the process accordingly. MF had low content even when: 1) Is added with gums such as CMC, and 2) Starch having a higher gelatinization as caused by the industrial MF method. It is important to mention that on dry basis differences were maintained.

Nutrient	Unit	Raw Material			P value
		MFA	MDB	MF/MDC	
		(n=111)	(n=78)	(n=105)	
Moisture	g	48.98 ± 4.94^a	43.05 ± 2.87^b	42.87 ± 2.44^b	0
	g*	48.02-49.94	42.51-43.59	42.32-43.42	
Protein	g	4.64 ± 0.56^a	5.17 ± 0.32^b	5.22 ± 0.28^b	0
	g*	4.53-4.74	5.11-5.23	5.16-5.29	
Energy	kJ	201.02 ± 19.87^a	223.16 ± 11.71^b	223.87 ± 9.64^b	0
	kJ*	197.17-204.86	220.96-225.37	221.70-226.04	
Crude fat	g	0.95 ± 0.20^a	1.24 ± 0.26^b	1.28 ± 0.23^b	0
	g*	0.91-0.99	1.19-1.29	1.23-1.34	
Ash	g	1.05 ± 0.26^a	1.14 ± 0.18^b	1.18 ± 0.16^b	0
	g*	1.00-1.10	1.11-1.17	1.14-1.21	
Dietary fiber	g	8.01 ± 1.22^a	8.50 ± 1.06^b	8.63 ± 1.25^b	0
	g*	7.78-8.25	8.30-8.70	8.35-8.91	
Calcium (Ca)	mg	122.88 ± 70.53^a	207.72 ± 64.67^b	197.99 ± 69.60^b	0
	mg*	109.23-136.53	195.56-219.88	182.30-213.68	
Iron (Fe)	mg	1.47 ± 0.97a	1.82 ± 0.62^b	2.02 ± 1.23^b	0
	mg*	1.28-1.66	1.71-1.94	1.74-2.29	
Zinc (Zn)	mg	1.16 ± 0.30	1.18 ± 0.19	1.14 ± 0.17	0.157
	mg*	1.10-1.21	1.14-1.21	1.10-1.17	
Riboflavin (B2)	mg	0.08 ± 0.07^a	0.04 ± 0.03^b	0.03 ± 0.02^b	0
	mg*	0.07-0.10	0.03-0.05	0.03-0.04	
Thiamine (B1)	mg	0.12 ± 0.11^a	0.04 ± 0.04^b	0.05 ± 0.05^b	0
	mg*	0.10-0.15	0.03-0.05	0.03-0.06	

**All nutrients are per 100 g fresh weight of edible food *Confidence interval 95% Same letters by row indicate no significant difference (p>0.05) ^{a}Maize flour, ^{b}Maize dough, ^{c}Maize flour/Maize dough

Table 2: Nutrients in maize tortillas by raw material** from 16 municipalities of Mexico City.

Calcium and Iron were significantly different between MF and MD. The latter was similar to MD/MF tortillas (Table 2). Calcium increased as a function of: 1) Maize phenotype, 2) Fractured grain percentage, and 3) Soaking time [8,27]. The higher calcium in MD tortillas may be due to: 1) longer nixtamalization and holding times, 12-18 h, even though lime amount added in each process varies considerably, TM using up to 1.2% and IM 5 to 6%; 2) Is possible that the grain used has a high % of broken grain that favours calcium diffusion, the affinity being pericarp>germ>endosperm [28]; or 3) Is caused by the lime addition to MD during kneading, before pressing it in a tortilla machine. This last practice was observed in tortilla shops and it is made with the aim of whitening and softening the product, as well as to help stop spoilage. On the other hand, calcium concentration affects tortilla moisture: at higher concentrations water absorption into starch is reduced [29]. This may explain the lower moisture in MD tortillas.

Iron in MD tortillas is of 1.5-1.7 mg [30]. In this study, MD tortillas (Tables 2 and 3) showed contents of about 2.0 mg. It's known iron is related to maize phenotype, since white maize has higher content as compared to yellow varieties and losses smaller amounts along process [9]. Therefore, longer holding time of nixtamal modifies it [8]. These considerations suggest that white maize is used in TM, while MF industry prefers yellow types [31].

Zinc contents among tortillas were not statistically different (Tables 2 and 3) between tortillas by raw material or point of sale. It's been reported that longer holding time of nixtamal has strongest effect on zinc because up to 11% of zinc may be lost as compared to initial content of grain [8]. Therefore, it's been observed that zinc in tortillas is related to maize phenotypes [32].

Nutrient	Unit	Point of sale		P value
		Tortilla shop (n=192)	Supermarket (n=102)	
Moisture	g	43.05 ± 2.74	49.01 ± 5.01	0
	g*	42.66-43.44	48.03-49.99	
Protein	g	5.19 ± 0.31	4.63 ± 0.56	0
	g*	5.14-5.23	4.52-4.74	
Energy	kJ	223.14 ± 11.08	200.94 ± 20.15	0
	kJ*	221.57-224.72	196.99-204.90	
Crude fat	g	1.25 ± 0.25	0.95 ± 0.20	0
	g*	1.22-1.29	0.92-0.99	
Ash	g	1.15 ± 0.17	1.05 ± 0.26	0.001
	g*	1.13-1.18	1.00-1.10	
Dietary fiber	g	8.54 ± 1.15	8.03 ± 1.21	0
	g*	8.38-8.71	7.79-8.26	
Calcium (Ca)	mg	201.99 ± 67.63	123.73 ± 71.33	0
	mg*	192.37-211.62	109.72-137.74	
Iron (Fe)	mg	1.90 ± 0.92	1.46 ± 0.98	0
	mg*	1.77-2.03	1.27-1.65	
Zinc (Zn)	mg	1.16 ± 0.19	1.16 ± 0.30	0.217
	mg*	1.13-1.19	1.10-1.22	
Riboflavin (B2)	mg	0.03 ± 0.03	0.08 ± 0.07	0
	mg*	0.03-0.04	0.07-0.10	
Thiamine (B1)	mg	0.04 ± 0.04	0.13 ± 0.11	0
	mg*	0.04-0.05	0.10-0.15	

**All nutrients are per 100 g fresh weight of edible food *Confidence interval 95%. Same letters by row indicate no significant difference (p>0.05)

Table 3: Nutrients in maize tortillas by point of sale** from 16 municipalities of Mexico City.

Riboflavin and thiamine contents decreases by alkaline cooking, with losses close to 50% and 70% for riboflavin and thiamine, respectively [31]. In present study, content depend on the manufacturing process or raw material. MF tortillas showed a 100% higher content of riboflavin, as well as 200% higher for thiamine than MD tortillas, it could be due to the OMS NOM-187, which establishes that MF shall be added with 0.3 and 0.5 mg/100 g of riboflavin and thiamine, respectively [33]. It is noteworthy that these two vitamins are absent in MD tortillas.

Variation of chemical composition of tortillas along the systematic sampling

Moisture in tortillas varied along sampling by raw material and point of sale (Tables 4 and 5). This may be due, in case of MD, to the lack control during manufacturing process. It is known that TM employs subjective techniques to evaluate final products [34]; which is confirmed by the variation observed in MD tortillas by point of sale. On the other hand, addition of MF to MD seems to stabilize moisture, although samples from different collections were statistically different, but p value was close to significance; what is clear is the higher moisture content of MF tortillas.

Nutrient / Sampling	Unit	MFA 1 (n=35)	MFA 2 (n=35)	MFA 3 (n=35)	P value	MDB 1 (n =37)	MDB 2 (n=37)	MDB 3 (n=37)	P value	MF/MDC 1 (n=26)	MF/MDC 2 (n=26)	MF/MDC 3 (n=26)	P value
Moisture	g	47.30 ± 4.03^{a}	49.93 ± 7.05^{b}	49.71 ± 2.10^{b}	0.003	44.49 ± 3.66^{a}	42.67 ± 1.83^{b}	42.00 ± 2.24^{b}	0.001	43.20 ± 2.68^{a}	43.50 ± 2.55^{a}	41.92 ± 1.79^{b}	0.049
Protein	g	4.92 ± 0.51^{a}	4.67 ± 0.65^{a}	4.32 ± 0.27^{b}	0	5.15 ± 0.42	5.23 ± 0.23	5.13 ± 0.30	0.315	5.28 ± 0.30	5.22 ± 0.28	5.16 ± 0.27	0.292
Energy	kJ	207.62 ± 16.40^{a}	197.42 ± 27.99^{b}	198.00 ± 9.34^{b}	0.009	217.13 ± 15.05^{a}	224.91 ± 7.23^{b}	227.46 ± 8.96^{b}	0.001	222.91 ± 10.27	221.46 ± 10.20	227.25 ± 7.58	0.132
Crude fat	g	0.98 ± 0.23	0.95 ± 0.23	0.93 ± 0.12	0.723	1.21 ± 0.34	1.26 ± 0.20	1.26 ± 0.21	0.769	1.38 ± 0.15^{a}	1.27 ± 0.27^{a}	1.21 ± 0.23^{c}	0.038
Ash	g	1.15 ± 0.25^{a}	1.03 ± 0.28^{a,b}	0.96 ± 0.19^{b}	0.007	1.09 ± 0.18^{a}	1.17 ± 0.19^{a,b}	1.17 ± 0.14^{b}	0.037	1.17 ± 0.16	1.17 ± 0.14	1.19 ± 0.18	0.964
Dietary fiber	g	8.25 ± 0.97	7.95 ± 1.33	7.84 ± 1.32	0.707	8.01 ± 1.07^{a}	8.65 ± 0.99^{b}	8.85 ± 0.97^{b}	0.002	8.06 ± 1.08^{a}	8.93 ± 1.51^{b}	8.91 ± 0.91^{b}	0.016
Calcium (Ca)	mg	126.96 ± 68.46	114.79 ± 56.94	126.91 ± 64.77	0.905	190.04 ± 69.60^{a}	209.66 ± 72.45^{a,b}	223.46 ± 45.86^{b}	0.018	164.00 ± 53.05^{a}	214.63 ± 86.10^{b}	215.34 ± 53.74^{b}	0.002
Iron (Fe)	mg	1.58 ± 0.46	1.42 ± 0.61	1.40 ± 0.61	0.481	2.03 ± 0.53^{a}	1.74 ± 0.75^{b}	1.70 ± 0.53^{b}	0.009	2.00 ± 0.57	2.20 ± 0.88	1.85 ± 0.84	0.343
Zinc (Zn)	mg	1.16 ± 0.34	1.16 ± 0.31	1.15 ± 0.24	0.579	1.05 ± 0.17^{a}	1.26 ± 0.17^{b}	1.22 ± 0.16^{b}	0	1.07 ± 0.10^{a}	1.13 ± 0.22^{a,b}	1.20 ± 0.16^{b}	0.011
Riboflavin (B2)	mg	0.09 ± 0.07	0.07 ± 0.07	0.09 ± 0.07	0.057	0.03 ± 0.02^{a}	0.03 ± 0.02^{a,b}	0.05 ± 0.03^{b}	0	0.02 ± 0.03^{a}	0.04 ± 0.02^{b}	0.04 ± 0.02^{b}	0.041
Thiamine (B1)	mg	0.13 ± 0.11	0.13 ± 0.10	0.12 ± 0.11	0.851	0.04 ± 0.04	0.04 ± 0.04	0.04 ± 0.04	0.617	0.05 ± 0.05	0.04 ± 0.04	0.05 ± 0.05	0.787

*All nutrients are per 100 g fresh weight of edible food, a Maize flour, b Maize dough, C Maize flour/Maize dough. Same letters by row and section indicate no significant difference (p>0.05)

Table 4: Variability in nutrients of maize tortillas by raw material* from 16 municipalities of Mexico City.

Protein Content (PC) of MD and MD/MF tortillas, both collected from TS, did not show significant differences along sampling (Tables 4 and 5). Addition of MF did not affect PC at any time. MD tortillas have higher PC and differences in manufacturing conditions between traditional establishments do not seem to affect PC. The results obtained may suggest that MF tortillas have lower protein contents and this may confirm that milling of alkaline-processed grain at low moisture, in IM, has an effect on protein.

Energy Content (EC) of tortillas was different along sampling, but only those of MD/MF did not show differences (p>0.05), which may be due to % of MF added. It's been reported that 30% of MF only improves texture characteristics of MD [34]; therefore we may say that addition percentages ≥ 30% could modify the EC of MD/MF tortillas.

Crude Fat (CF) content in tortillas by raw material was not different at sampling, except for MD/MF samples. In MD tortillas, even though processing conditions vary between establishments; and in MF tortillas, since it is common, containing additives to obtain particular characteristics in final product. The consistently lower CF in all MF samples may confirm that a different phenotype is used by MF industry.

Ash content varied along sampling for both MD and MF tortillas. Variation of ash could be attributed to differences in pericarp removal or to amount of lime added during maize nixtamalization. As shown by the results, tortillas obtained by TM contain more ashes as given by process itself; or by manufacturer's addition when trying to achieve higher yields. However, this hasn't been corroborated yet.

Dietary Fiber (DF) in MF tortilla samples did not vary along time. This is explained by addition of hydrocolloids polymers or gums in order to control their functional properties. Industry includes these additives according to maize characteristics to be processed. On the other hand, DF variations of MD samples may be due to cooking temperature and longer holding times, which increases resistant starch content [35]. Cooking temperatures of tortillas on hot plates or machines may also be a factor, since it causes starch pyro-dextrinization and production of free polysaccharides, which increases non-digestible carbohydrates [36].

Calcium, Iron and Zinc contents in MF samples did not show variations along sampling. It is noteworthy that stirring, cooking time and holding time are factors that determine the degree of calcium incorporation into the grain [37]. Therefore, differences in MD tortillas indicate that amount of calcium hydroxide or magnitude of parameters mentioned above may vary considerably between establishments.

Nutrient	Unit	Tortilla shop			P value	Supermarket			P value
Sampling		1	2	3		1	2	3	
		(n=64)	(n=64)	(n=64)		(n=34)	(n=34)	(n =34)	
Moisture	g	43.99 ± 3.31[a]	43.09 ± 2.24[a]	42.08 ± 2.22[b]	0	47.32 ± 4.09[a]	49.99 ± 7.15[b]	42.00 ± 2.13[b]	0.003
Protein	g	5.20 ± 0.37	5.22 ± 0.25	5.14 ± 0.29	0.173	4.91 ± 0.52[a]	4.66 ± 0.66[a]	4.31 ± 0.26[b]	0
Energy	kJ	219.33 ± 13.48[a]	223.16 ± 8.98[a]	226.94 ± 8.99[b]	0.001	207.62 ± 16.64[a]	197.26 ± 28.39[b]	197.96 ± 9.48[b]	0.012
Crude fat	g	1.27 ± 0.30	1.26 ± 0.23	1.24 ± 0.22	0.54	0.99 ± 0.23	0.95 ± 0.23	0.93 ± 0.12	0.511
Ash	g	1.12 ± 0.18	1.17 ± 0.17	1.18 ± 0.16	0.109	1.15 ± 0.26[a]	1.03 ± 0.29[a,b]	0.96 ± 0.20[b]	0.007
Dietary fiber	g	7.99 ± 1.09[a]	8.78 ± 1.22[b]	8.86 ± 0.94[b]	0	8.32 ± 0.88	7.91 ± 1.33	7.84 ± 1.34	0.468
Calcium (Ca)	mg	177.57 ± 65.11[a]	210.16 ± 78.11[b]	218.26 ± 50.83[b]	0	128.66 ± 68.73	114.86 ± 57.79	127.66 ± 85.93	0.845
Iron (Fe)	mg	2.01 ± 0.54[a]	1.93 ± 1.33[b]	1.76 ± 0.67[b]	0.005	1.57 ± 1.48	1.40 ± 0.61	1.40 ± 0.62	0.463
Zinc (Zn)	mg	1.06 ± 0.15[a]	1.20 ± 0.20[b]	1.21 ± 0.16[b]	0	1.15 ± 0.34	1.17 ± 0.31	1.15 ± 0.24	0.403
Riboflavin (B2)	mg	0.03 ± 0.03[a]	0.03 ± 0.02[a]	0.05 ± 0.03[b]	0	0.09 ± 0.07[a]	0.08 ± 0.07[a]	0.09 ± 0.07[b]	0.049
Thiamine (B1)	mg	0.04 ± 0.04	0.04 ± 0.04	0.04 ± 0.04	0.855	0.13 ± 0.12	0.13 ± 0.10	0.12 ± 0.11	0.89

*All nutrients are per 100 g fresh weight of edible food. Same letters by row and section indicate no significant difference (p>0.05)

Table 5: Variability in nutrient composition of maize tortillas by point of sale* from 16 municipalities of Mexico City.

Iron and zinc are added in amounts of 40 mg/kg of MF, and per 100 g of tortillas the expected amount is of 1.62 mg of each, and these do not take into account mineral contents naturally present in maize; concentrations of these minerals in MF tortillas were lower; this may be due to a decrease during storage, iron decreases around 10%, and zinc remains constant after two months [38]. Given the above, losses seem to be around ≥15% for iron, and ≥30% for zinc.

Riboflavin and thiamine in MF tortillas were not statistically different along collections. This is due to fortification of MF, as mentioned, that is of 3 and 5 mg/kg of MF, of vitamins B2 and B1, which results in 0.12 and 0.20 mg/100 g of tortillas, respectively. However, concentrations of B1, B2 in tortillas were lower; this may be due to a decrease in vitamin content during storage, which is between 18 to 37%. When tortillas are prepared, vitamins decrease 37% further [38]. Given the above, losses seem to be around 40% for vitamins.

In MD tortillas, only thiamine did not show differences along collection period; however it was found in low concentrations that indicate a probable total loss. The addition of MF to MD, In MD/MF tortillas, seems to compensate the variation in vitamins contents.

Conclusion

Statistical differences observed in chemical composition of tortillas by raw material, particularly those found for crude fat and iron are due to maize phenotype, while those observed for dietary fiber are due to pericarp removal addition of additives. Significant difference in protein and ash contents, are due to losses during nixtamalization. Regarding ash, amount of lime added didn't seem to cause a difference, as opposed to variations in pericarp removal.

Differences in composition along sampling in MD tortillas may be due to variations in time and cooking temperature, as well as in holding time given by each establishment. However, protein and crude fat wasn't affected in final product.

Not having found variations along time in crude fat, crude fiber, calcium, iron, zinc, thiamine and riboflavin in MF tortillas are due to additives added whose purpose is to improve rheological characteristics of tortillas, as well as to fortify the product.

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