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Agroquímicos y presencia de aflatoxinas en maíz de temporal almacenado: riesgos para la seguridad alimentaria en el estado de Tlaxcala, México

Aflatoxins presence and agrochemicals in stored temporary corn: security foods´s risks in Tlaxcala state, Mexico

Agroquímicos e presença de aflatoxinas no milho armazenado temporariamente: riscos para a segurança alimentar no estado de Tlaxcala, México

Guillermina García Juárez
Universidad Autónoma de Tlaxcala, Facultad de Agrobiología, México
nefertiti_ggj58@yahoo.com
https://orcid.org/0000-0003-4943-454X

Maricela Hernández Vázquez
Universidad Autónoma de Tlaxcala, Facultad de Agrobiología, México
mariheva@live.com.mx
https://orcid.org/0000-0003-4562-2324

Hermila Orozco Bolaños
Universidad Autónoma de Tlaxcala, Facultad de Agrobiología, México
emy_r1@yahoo.com
https://orcid.org/0000-0001-5519-1893

Gerardo Suárez González
El Colegio de Tlaxcala A. C., México
gersuaovis@hotmail.com
https://orcid.org/0000-0002-8452-1625

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Resumen

La producción de maíz se ve afectada por diversas variables climáticas (sequía, exceso de lluvia, etc.), así como por diferentes microorganismos (como el *Aspergillus*, generador de las aflatoxinas), los cuales suelen ser combatidos a través de ciertos agroquímicos que, de forma colateral, también pueden afectar el ambiente y la salud de las personas. Por esta razón, el objetivo de este trabajo fue establecer una relación entre la variabilidad climática, el uso de agroquímicos y la presencia de aflatoxinas en sistemas de almacenamiento de maíz, factores que en el estado de Tlaxcala no han sido analizados previamente. Esta investigación, de tipo transversal-analítica, fue desarrollada en el periodo de mayo-diciembre de 2018. Los municipios seleccionados fueron incluidos según los siguientes criterios: 1) número de productores de maíz de temporal, 2) producción de maíz en toneladas y 3) producción de maíz promedio en el periodo 2001-2017. Los datos se obtuvieron del Sistema de Información Agroalimentaria y Pesquera (SIAP). La técnica empleada fue la encuesta, mientras que el muestreo usado fue de tipo incidental. El análisis estadístico de los factores de riesgo se realizó bajo los criterios para variables cualitativas con la prueba de Rho Spearman, en el programa SPSS, versión 21. Los resultados demuestran que 49 % de los agricultores tienen entre 61 y 68 años de edad y que, en promedio, 91 % de los productores usa algún tipo de agroquímico. Asimismo, y a pesar de que 77 % siembra más de 2 ha, solo 47 % cosecha en promedio 2 ton en total. Igualmente, 91 % del maíz es para consumo familiar; 64 % de los agricultores almacena en granero o bodega de tipo abierto, aunque las condiciones de saneamiento son deficientes en 75 % de los casos. En general, la producción de maíz tiene riesgos en la inocuidad por el uso de plaguicidas y fertilizantes químicos, así como deficientes condiciones en los sistemas de almacén. De hecho, 100 % de las muestras de maíz resultaron contaminadas con aflatoxinas, aunque dentro de los niveles permisibles por la NOM-187-SSA1/SCFI-2002. La aplicación de agroquímicos mostró asociación estadística significativa con la producción de maíz de temporal, excepto en Tlaxco. La presencia de aflatoxinas es una constante en todos los municipios, por lo que no existe inocuidad en el maíz almacenado. Estos factores representan riesgos para la seguridad alimentaria en los principios de accesibilidad-abasto e inocuidad.

Palabras clave: accesibilidad de alimentos, inocuidad alimentaria, fertilizantes, plaguicidas, toxinas.

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Abstract

The corn production looks affected by several climatics variables (drought, rain excess, etc)., as well as by different microorganisms (such as *Aspergillus*, aflatoxins producers), which are usually fought through certain agrochemicals that collaterally can affect the environment and the people`s health. For this reason, the objective of this work was to establish a relation between the climatic variability, agrochemical use and aflatoxins presence in the corn storage systems, factors that in Tlaxcala state has not been previously analyzed. This research, cross sectional analytical type, was developed during May- December 2018. The municipalities selected were included according to the following criteria: 1) number of temporary corn producers, 2) corn production in tons and 3) average corn production during 2001 – 2017. The data was obtained from the agri-food and fisheries information system (SIAP). The technique used was the poll, while the sampling used was the incidental type. The statistical analysis of the risk factors was made under the criteria for qualitative variables with the Rho Spearman test, in the software SPSS 21 version. The results show that the 49% of farmers are between 61 and 68 years old, and in average the 91% use some kind of agrochemical. Likewise, and even though the 77% sow more than 2 hectares, only the 47% harvest in average 2 tons in total. Equally the 91% of the corn is for family consumption; the 64% of the farmers store their grains in open storages or barns, though the sanitation conditions are deficient in 75% of the cases. In general, the corn production has risks in the harmlessness by the use of pesticides and chemical fertilizers, as well as deficient conditions in the storage systems. In fact, the 100% of the corn samples turned out contaminated by aflatoxins, though within permissible levels by the NOM-187-SSA1/SCFI-2002. The use of agrochemicals showed a statistically significant association with the temporary corn production, except in Tlaxco. The aflatoxins presence is a constant in all the municipalities, so it doesn`t exist harmlessness in the stored corn. This factors represent risks for the food safety in the principles of accessibility-supply and harmlessness.

Keywords: food accesibility, food harmlessness, fertilizers, pesticides, toxins.

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Resumo

A produção de milho é afetada por várias variáveis climáticas (seca, excesso de chuvas, etc.), bem como por diferentes microorganismos (como Aspergillus, gerador de aflatoxinas), que geralmente são combatidos por determinados agroquímicos que, Colateralmente, eles também podem afetar o ambiente e a saúde das pessoas. Por esse motivo, o objetivo deste trabalho foi estabelecer uma relação entre variabilidade climática, uso de agroquímicos e presença de aflatoxinas em sistemas de armazenamento de milho, fatores que no estado de Tlaxcala não foram analisados anteriormente. Esta pesquisa analítica cruzada foi realizada no período de maio a dezembro de 2018. Os municípios selecionados foram incluídos de acordo com os seguintes critérios: 1) número de produtores temporários de milho, 2) produção de milho em toneladas e 3) produção média de milho no período 2001-2017. Os dados foram obtidos no Sistema de Informação Agropecuária e Pesca (SIAP). A técnica utilizada foi a pesquisa, enquanto a amostragem utilizada foi incidental. A análise estatística dos fatores de risco foi realizada sob os critérios para variáveis qualitativas com o teste Rho Spearman, no programa SPSS, versão 21. Os resultados mostram que 49% dos agricultores têm entre 61 e 68 anos de idade e que Em média, 91% dos produtores utilizam algum tipo de agroquímico. Da mesma forma, e apesar de 77% semear mais de 2 ha, apenas 47% colhem uma média de 2 toneladas no total. Da mesma forma, 91% do milho é para consumo familiar; 64% dos agricultores armazenam em um celeiro ou adega de tipo aberto, embora as condições de saneamento sejam deficientes em 75% dos casos. Em geral, a produção de milho apresenta riscos em segurança devido ao uso de pesticidas e fertilizantes químicos, além de más condições nos sistemas de armazenagem. De fato, 100% das amostras de milho estavam contaminadas com aflatoxinas, embora dentro dos níveis permitidos de NOM-187-SSA1 / SCFI-2002. A aplicação de agroquímicos mostrou associação estatística significativa com a produção de milho temporário, exceto em Tlaxco. A presença de aflatoxinas é uma constante em todos os municípios, portanto, não há danos no milho armazenado. Esses fatores representam riscos para a segurança alimentar nos princípios de acessibilidade, fornecimento e segurança.

Palavras-chave: acessibilidade alimentar, segurança alimentar, fertilizantes, pesticidas, toxinas.

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Introduction

Agriculture is an elementary activity for food production of any society in the world. However, this work depends largely on environmental conditions, mainly in areas where there is a lack of infrastructure for irrigation and control of temperature, wind, precipitation and relative humidity. For this reason, producers rely on the use of fertilizers to increase soil nutrients and strengthen the crop against the attack of pathogens and pests. In this regard, González and Juárez (2016) point out that producing food under temporary conditions has implicit risks, with significant effects for quantity, quality and safety, as well as for the livelihoods of farmers in different socioeconomic regions.

In Mexico, the variety of ecosystems has areas that have unstable geographical-climatic conditions in terms of rainfall, temperature and the low layer of fertile soil (Mera and Mapes, 2009), which violates agricultural production. Mexico is an important producer and consumer of grains, of which corn (Zea mayz L.) stands out for the great variety of uses that can be given for human and animal consumption (Martínez, Hernández, Reyes and Vázquez, 2013), although it must also be said that between 80% and 90% of the production of this food is temporary (Turrent, Wise and Garvey, 2012), so that it is exposed to the effects of climatic variability.

In the state of Tlaxcala, geographically located in the Mexican highlands, the production and consumption of corn has been of great importance since pre-Hispanic times. In fact, the value of this product is implicit in the etymological meaning of that entity, since Tlaxcala is of Nahuatl origin tlaxcalli, which means 'tortilla, place of corn or tortillas' (Encyclopedia of municipalities and delegations of Mexico, 2016). Therefore, it can be said that the production of this grain has a socio-cultural richness for the region and is part of the daily menu offered in different presentations.

However, the main effects of climate change facing the cultivation of temporary corn in the state of Tlaxcala are seasonal variation, changes in temperature and humidity, phenomena that cause imbalances in the soil microbiota and violate the plant, what causes the proliferation of plagues that damage it mechanically and cause the invasion of microorganisms such as Aspergillus flavus (Hernández, García, Orozco and Juárez, 2018).

The genus Aspergillus synthesizes mycotoxins, among which is the aflatoxin group, which violates the safety of maize mainly in storage with poor ventilation (Juárez, Bárcenas and

Hernández, 2014; Martínez et al., 2013), which represents a risk to food security of man and animals (Devreese, De Backer and Croubels; Mirón, 2017). The Aspergillus genus develops with relative humidity levels that range between 70% and 90% at temperatures above 25 ° C, although it is worth noting that these measures are not determinant, since in European countries their development is observed at less than 20 ° C (Miraglia et al., 2009).

The production of aflatoxin varieties occurs between 11 ° C and 35 ° C, with an optimum temperature of 22 ° C and ideal humidity ranging from 80% to 90%. These microorganisms occur in adverse climates, especially when there are poor storage conditions. In addition, they are thermostable and resistant to degradation under normal cooking procedures, hence it is difficult to eliminate them once they occur (Mejía, Alvarado and Vásquez, 2014). Its natural habitat is the soil and tissue of plants such as corn (Rojas, Gutiérrez, Orantes and Manzur, 2017).

According to the Food and Agriculture Organization of the United Nations (FAO) (2018), it was determined that it is vital that the population has food security, which is reflected in the quality and safety of the products. Therefore, one of the basic principles promoted by FAO (2011) is that all people, at all times, have "physical and economic access to sufficient food, safe and nutritious, to meet their nutritional needs and preferences, with the object of leading an active and healthy life "(p. 2). In contrast, food contaminated with a pathogen or toxin reduces supply and puts human health at risk (Aguirre, García, Vázquez, Alvarado y Romero, 2017).

Even so, aflatoxins can be found at different points in the food chain. In Mexico, for example, corn for human consumption is regulated by the Official Mexican Standard NOM-188-SSA1- / SCFI-2002, which establishes a maximum permissible limit of aflatoxins in corn of 20 µg / kg, while for In the case of animals, their limit is between 21 µg / kg and 300 µg / kg. In the European Union, on the other hand, the maximum aflatoxin content in corn, before direct human consumption or as an ingredient in food products, is 5 µg / kg for aflatoxin B1 and 10 µg / kg for the sum of B1, B2, G1 and G2 (Official Journal of the European Union, 2006). This differential of concentrations is important because it is necessary to consider the quality and safety of food for people with different biological conditions and with certain predispositions to present alterations in health.

As explained in the previous paragraphs, this research has attempted to establish a relationship between climate variability, the use of agrochemicals and the presence of aflatoxins in

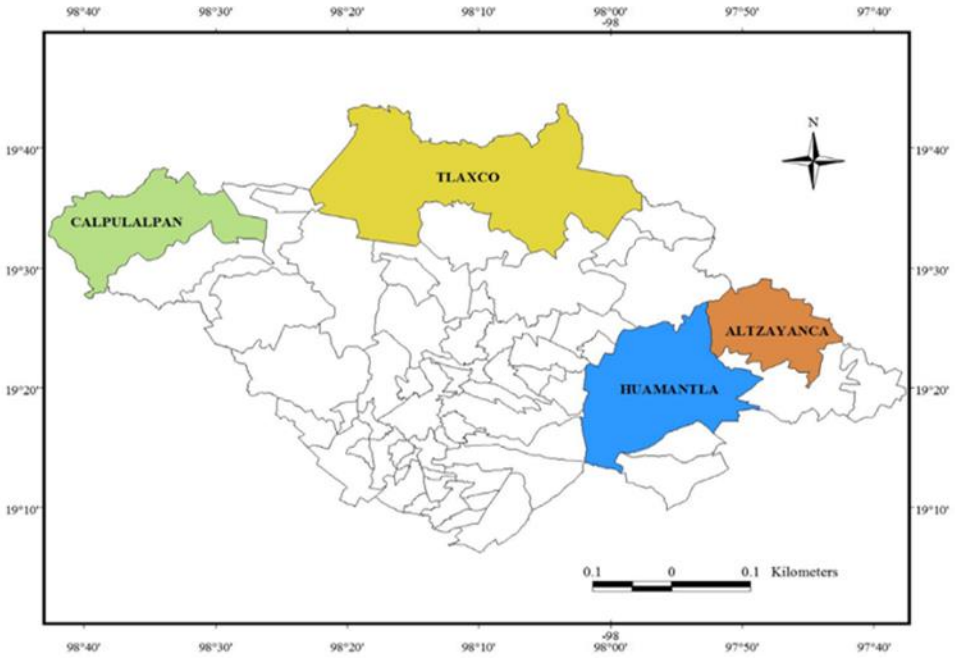
corn storage systems, factors that have not been analyzed in previous studies of the state from Tlaxcala.

Material and method

Study area

This cross-analytical research was carried out in the period of May-December 2018. The selected municipalities (figure 1) were included according to the following criteria: 1) number of temporary corn producers, 2) corn production in tons and 3) average corn production in the period 2001-2017. The data were obtained from the Agrifood and Fisheries Information System (SIAP) (2018).

Figura 1. Localidades seleccionadas para el estudio de agroquímicos y presencia de aflatoxinas en almacenamiento en el estado de Tlaxcala



Fuente: Elaboración propia

The technique used was the survey, while the sampling used was incidental (Garriga et al., 2015). The phases of the investigation were the following:

1. Characteristics in the production systems: To this end, a questionnaire was designed with the sections General data, Characteristics in the production of corn, Destination of the harvest and local banks of the germplasm, with a total of 35 questions. To validate the instrument, a pilot test of 20 questionnaires was applied in the study municipalities.
2. Environmental conditions in the storage systems: The temperature and relative humidity in the corn storage systems with Beaurer HM 16 digital thermohygrometer were measured, although when the product was in sacks a red liquid thermometer was used -10 a 200 DUVE long type. Samples of 1 kg of corn were taken using a Rotter dynamometer with a capacity of 12 kg. Sterile gloves were also worn and placed in previously labeled sterile bags. The sampling technique was based on the methodological recommendations of the Official Mexican Standard (NOM-247-SSA1-2008) both for seed in sacks and on mounds. The preservation and transportation of the samples was carried out in a large Naviempaques 751 refrigerator with ice. A cardboard pallet was used not to wet the samples, which were placed the same day in the analysis laboratory.
3. Identification of aflatoxins in corn in storage systems: A total of 200 samples were obtained from the stored crop. At the laboratory level, aflatoxin detection was performed with the Enzyme-Linked ImmunoSorbent Assay (ELISA) test. The size was assigned proportionally based on the following selection criteria: Altzayanca-60, Huamantla-60, Tlaxco-50 and Calpulalpan-30.
4. Risks in food safety: It was evaluated with the variables a) decrease in corn production per hectare, b) use of chemical fertilizers, c) chemical control of pests and d) presence of aflatoxins.

Statistic analysis

The data obtained from the applied questionnaire were analyzed descriptively. The risk factors in the production of corn and aflatoxins in storage were calculated with criteria for qualitative variables with the Rho Spearman test in the SPSS program, version 21. The null hypothesis was considered equal to 0 and the alternative ± 0 with level of bilateral significance (determined by the analysis at 95 % y 99 % y *p-valor* ≤ 0.05).

Results

Characteristics in the production of temporary corn

Table 1 shows the main features. In summary, it can be said that 49% of farmers are between 61 and 68 years old. On average, 91% of producers use some type of agrochemical. Likewise, and despite the fact that 77% sow more than 2 ha, only 47% harvest an average of 2 tons in total. Similarly, 91% of the corn is for family consumption; 64% of farmers store in barn or open type cellar. Sanitation conditions are deficient in 75% of cases. It is also observed that agricultural practices fall on the elderly. In general, corn production has safety risks due to the use of pesticides and chemical fertilizers, as well as poor conditions in warehouse systems.

Tabla 1. Características en la producción de maíz de temporal

Características	Altzayanca %	Calpulalpan %	Huamantla %	Tlaxco %	Promedio %
Rango de edad de los productores entre 61-68 años	**38**	**90**	**28**	**38**	**49**
Rotación de cultivos maíz, frijol y haba	77	63	93	90	81
Uso de fertilizantes químicos	**96**	**90**	**87**	**96**	**92**
Uso de plaguicidas químicos	**83**	**90**	**83**	**100**	**89**
Semilla blanca nativa variedad más sembrada	83	60	70	98	78
Superficie sembrada > de 2 ha	**90**	**57**	**78**	**84**	**77**
Promedio de producción 2 ton/cosecha	**53**	**24**	**57**	**52**	**47**
Destino del maíz para consumo familiar	**98**	**70**	**100**	**94**	**91**
Destino del maíz contaminado alimento de animales	98	90	70	98	89
Condiciones de buen secado para almacenar el maíz	98	99	98	100	99
Uso de bodega y granero abierto para almacenamiento	**52**	**97**	**30**	**78**	**64**
Condiciones sanitarias deficientes de almacenamiento	**72**	**86**	**64**	**79**	**75**

Fuente: Elaboración propia

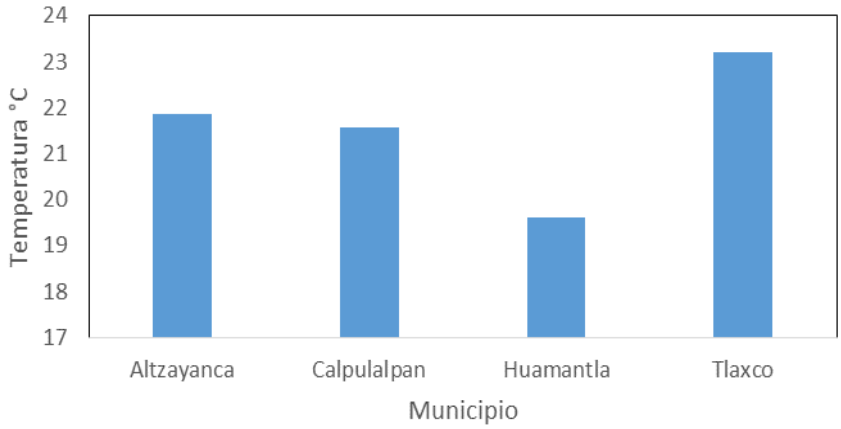
Environmental conditions in storage systems

For the preservation of the seed, optimum temperature and relative humidity are required to keep the grains in good quality and safety, as well as having sufficient supply for the consumption of the peasant families. These aspects are explained in more detail below:

Temperature

Figure 2 shows the average temperature that was recorded in the study regions. In Tlaxco, the highest temperature was observed at 23 ° C. These measurements are within the safe parameters for the conservation of seeds in good condition. However, “cuexcomate” warehouses from Cuexcomatl del Nahuatl (a warehouse that means significa clay pot ’) were found more frequently in this municipality, exposed to the inclement weather.

Figura 2. Temperatura promedio en los sistemas de almacenamiento

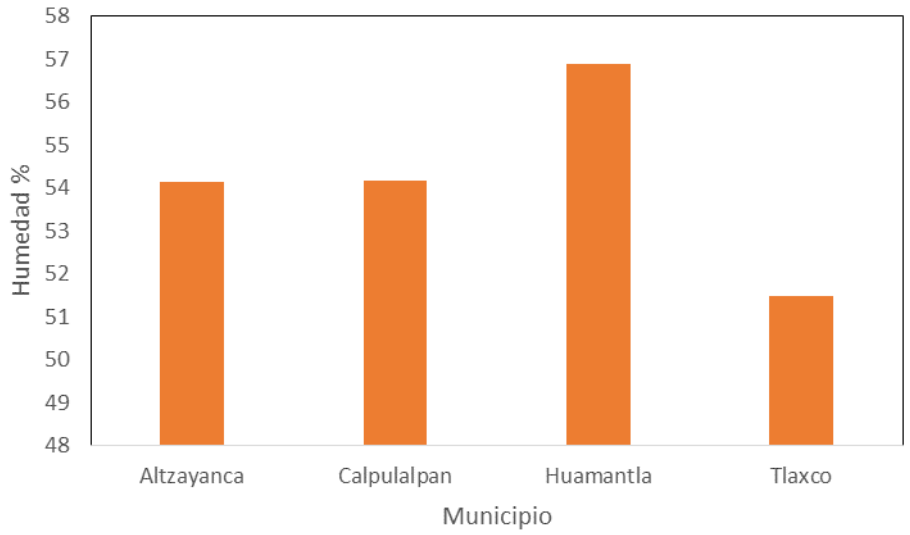


Fuente: Elaboración propia

RH

Figure 3 shows the average relative humidity of the warehouse. The municipality of Huamantla presented the highest record with 57%. These humidity levels provide a degree of protection to prevent the development of fungi, pests and toxins. However, other factors such as poor sanitary conditions, presence of rodents, etc., that may affect the development of biosynthesizing fungi of aflatoxins should be considered.

Figura 3. Promedio de humedad relativa en los sistemas de almacenamiento

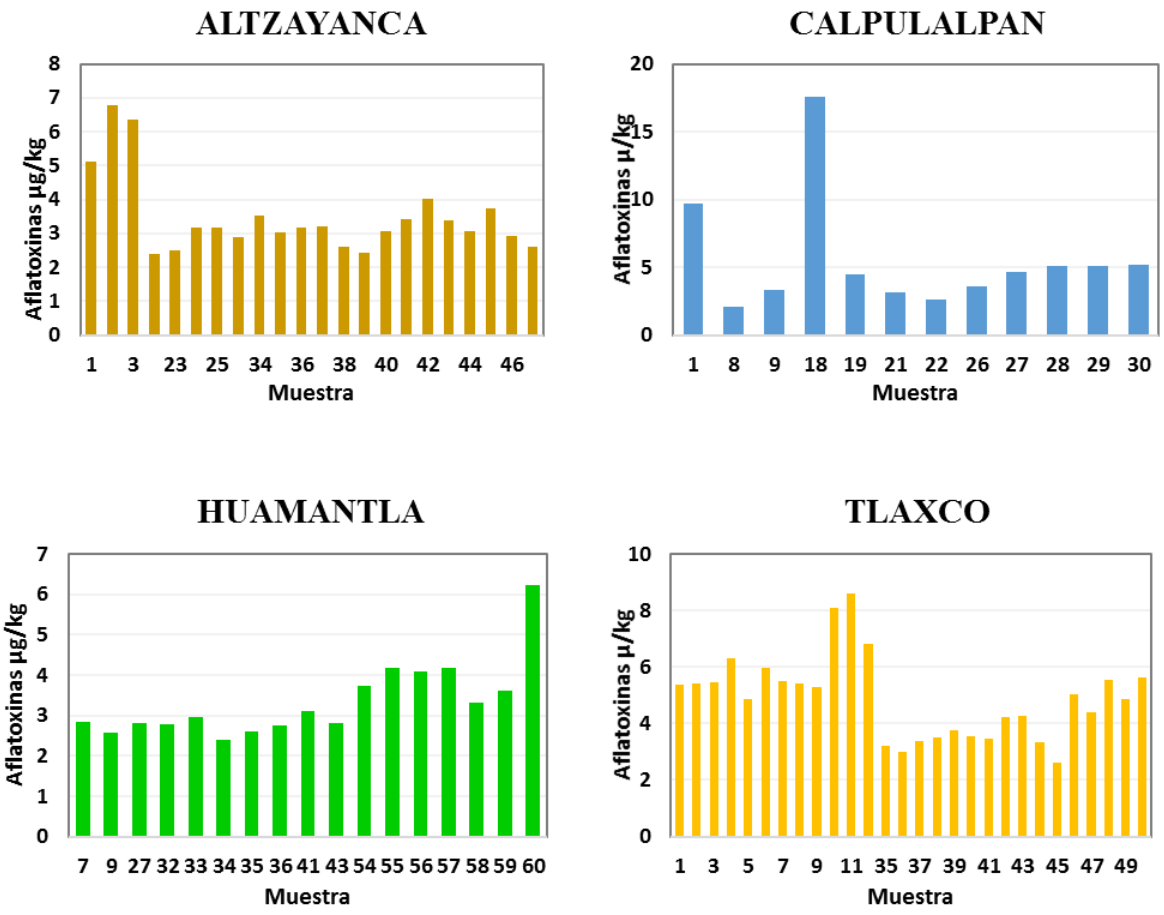


Fuente: Elaboración propia

Identification of aflatoxins in temporary storage corn

In general, the levels of aflatoxins identified in the study municipalities are presented in Figure 4. In this regard, 100% were positive by the ELISA test. The levels were within the permissible according to the Standard in Mexico (20 µg / kg) for corn (NOM-188-SSA1- / SCFI-2002). For descriptive purposes, levels <2 µg / kg were not plotted. These findings are important, because although the levels were low, they are factors for the cause-effect in the contamination of the seed due to the toxic properties of aflatoxins.

Figura 4. Niveles detectados de aflatoxinas en los municipios de estudio en Tlaxcala



Fuente: Elaboración propia

Food Security Risks

When analyzing the correlation of the variables use of chemical fertilizers and pesticides used in the production of temporary corn, as well as the presence of aflatoxins in storage systems, the impact on food security in terms of production and safety by municipality could be verified study.

In this regard, Spearman's Rho correlation test was performed to verify the degree of dependence between the mentioned variables. The analysis in the region of Atlzayanca (table 2) showed a significant correlation at 99% with a coefficient of .415 between the variables use of fertilizers and chemical control of pests. In addition, there was a statistically significant correlation

of .415 between chemical control of pests and decreased production. Agrochemicals and the presence of aflatoxins are latent risks in food safety due to lack of safety.

Tabla 2. Correlación región Altzayanca

			Uso de fertilizantes químicos	Control químico de plagas	Maíz contaminado con aflatoxinas	Disminución de la producción de maíz por ha
Rho de Spearman	Uso de fertilizantes químicos	Coeficiente de correlación	1	.415**	.	1.000**
		Sig. (bilateral)	.	0.001	.	.
		N	60	60	60	60
	Control químico de plagas	Coeficiente de correlación	.415**	1	.	.415**
		Sig. (bilateral)	0.001	.	.	0.001
		N	60	60	60	60
	Maíz contaminado con aflatoxinas	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	60	60	60	60
	Disminución de la producción de maíz por ha	Coeficiente de correlación	1.000**	.415**	.	1
		Sig. (bilateral)	.	0.001	.	.
		N	60	60	60	60

**. La correlación es significativa al nivel 0,01 (bilateral).

Fuente: Elaboración propia

In Calpulalpan (table 3), the correlation coefficient is .604 with p-contrast values less than 0.05. This demonstrates a strong mutual dependence, pointing to a significant 99% correlation between the use of agrochemicals and a decrease in corn production. On the other hand, corn contaminated with aflatoxins is not dependent on the aforementioned variables. This explains the presence of this toxic in all samples, in addition to the double negative effect with agrochemicals, so the availability of contaminant-free food is not met, which puts food safety at risk.

Tabla 3. Correlación región Calpulalpan

			Uso de fertilizantes químicos	Control químico de plagas	Disminución de la producción de maíz por ha	Maíz contaminado con aflatoxinas
Rho de Spearman	Uso de fertilizantes químicos	Coeficiente de correlación	1	1.000**	.604**	.
		Sig. (bilateral)	.	.	0	.
		N	30	30	30	30
	Control químico de plagas	Coeficiente de correlación	1.000**	1	.604**	.
		Sig. (bilateral)	.	.	0	.
		N	30	30	30	30
	Disminución de la producción de maíz por ha	Coeficiente de correlación	.604**	.604**	1	.
		Sig. (bilateral)	0	0	.	.
		N	30	30	30	30
	Maíz contaminado con aflatoxinas	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	30	30	30	30
**. La correlación es significativa al nivel 0,01 (bilateral).						

Fuente: Elaboración propia

The test carried out in the Huamantla region (table 4) showed a correlation coefficient of .877 between the chemical fertilizer use and chemical pest control variables. The result indicates that there is very high negative dependence. This evidences an important problem of food security due to the deterioration they cause in soils and ecosystems, with a decrease in agricultural production and food contamination. The presence of aflatoxins was positive in the total samples. This factor represents a latent risk to corn safety.

Tabla 4. Correlación región Huamantla

			Uso de fertilizantes químicos	Control químico de plagas	Maíz contaminado con aflatoxinas	Disminución de la producción de maíz por ha
Rho de Spearman	Uso de fertilizantes químicos	Coeficiente de correlación	1	.877**	.	.
		Sig. (bilateral)	.	0	.	.
		N	60	60	60	60
	Control químico de plagas	Coeficiente de correlación	.877**	1	.	.
		Sig. (bilateral)	0	.	.	.
		N	60	60	60	60
	Maíz contaminado con aflatoxinas	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	60	60	60	60
	Disminución de la producción de maíz por ha	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	60	60	60	60

**. La correlación es significativa al nivel 0,01 (bilateral).

Fuente: Elaboración propia

In Tlaxco (table 5), the analysis of the variables in question showed no correlation. The result indicates that the variables have the same variation, that is, there is a threat to food security, since the safety principle is not met.

Tabla 5. Correlación región Tlaxco

			Uso de fertilizantes químicos	Control químico de plagas	Maíz contaminado con aflatoxinas	Disminución de la producción de maíz por ha
Rho de Spearman	Uso de fertilizantes químicos	Coeficiente de correlación	1	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	50	50	50	50
	Control químico de plagas	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	50	50	50	50
	Maíz contaminado con aflatoxinas	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	50	50	50	50
	Disminución de la producción de maíz por ha.	Coeficiente de correlación	.	.	.	.
		Sig. (bilateral)	.	.	.	.
		N	50	50	50	50

Fuente: Elaboración propia

Discussion

Temporary agriculture is a primary activity that prevails in the production of corn in the state of Tlaxcala. To this end, producers challenge different weather eventualities and risks in the harvest (Hernández et al., 2015), among which Aspergillus flavus, a fungus that generates aflatoxins that contaminate the grain.

However, this study has shown that almost half of the producers are of advanced age (between 61-68 years), which coincides with the findings of Peralta, Carrazón and Zelaya (2012), who explain that the group of Grain farmers are getting older. Therefore, it is necessary that there is a generational change that can ensure the food security of the population.

On the other hand, it is also worth noting that most of the producers do crop rotation, because they associate corn-beans and beans, mainly. This practice is a strength for food production, since they protect the soil from erosion, reduce water temperature and evaporation, provide nutrients and mitigate the effects of climate change (Martín and Rivera, 2015), fundamental initiatives for Food security in agricultural practices.

However, it should also be noted that in the four regions analyzed the use of agrochemicals (pesticides and chemical fertilizers) was observed, which accelerate environmental pollution, cause soil infertility and threaten food quality and safety. According to Del Puerto Rodríguez, Suárez and Palacio (2014), these types of practices are usually used by farmers to control pests and improve "soil depletion", although without anticipating the negative effects they cause (Guerrero, 2018). As Mirón (2017) points out, these types of implements constitute a high cost not only for the economic investment they demand, but also for the damages they cause to people and the environment, despite the fact that - as highlighted by Hernández and Hansen (2011) - some of these products have been banned or limited in use in 2008 by the World Health Organization and the European Community.

As for the amount of corn harvested, it should be noted that 77% of farmers sow more than 2 ha, of which they get an average of 2 ton per harvest, a similar figure (2.43 ton / ha) to that reported by Orozco, García, Hernández and Juárez (2016) in a perception study in the state of Tlaxcala.

With regard to storage, most store corn in an open-type cellar or barn with a roof, under poor sanitary conditions, exposed to inclement weather and to excreta of dogs, cats and rodents. On this aspect, Doria (2010) points out that the reasons why the seeds should be stored are mainly to preserve them for a short period (from harvest to next planting). In this sense, the aforementioned author also indicates that open-type warehouses (the most used for their economy) do not serve to control humidity or temperature, and do not protect the product from contamination that can cause various animals, microorganisms and toxins , which affect the quality and safety of the grain. Therefore, it is vital to consider the ecological triad (Piedrola, 2003) on which the present study has been based, that is, a) aetiological agent: Aspergillus flavus-aflatoxins, pesticides and chemical fertilizers, b) host: corn in its different growth stages, and c) environment: geographical aspects and climatic variability, storage conditions (humidity and temperature).

In addition to the above, it should be anticipated that stored grains constitute a complex agroecosystem due to factors such as light, temperature, humidity, biotic agents (such as insects, fungi) that affect seed quality (Neethirajan, Karunakaran , Jayas and White, 2007; Olakojo and Akinlosotu, 2004).

Finally, regarding the levels of aflatoxins found in maize under storage systems, it could be indicated that these were within the standards allowed by NOM-187-SSA1 / SCFI-2002. Even so, it should be anticipated that the toxic properties of that microorganism may constitute an imminent risk to the safety of maize in all regions of this investigation. In this regard, it is worth mentioning the studies by Martínez et al. (2013) and Montes, Reyes, Montes and Cantú (2009), who highlight how climate variability can promote the development of Aspergillus and the biosynthesis of aflatoxins, mainly in countries whose climate is humid and warm, although it can also happen when produces a minimum increase in temperatures, which favors the development of these toxic substances, such is the case of the municipalities included in this research, which have a temperate-cold climate, with an average annual temperature of 14 ° C.

On aflatoxins, Carvajal (2013) explains that the toxic effects of these microorganisms are cumulative; This means that when the grain is contaminated (whether in the field, in storage or in processing), the effects may persist even after digestion, which causes different damage to animals and people. In some cases, the minimum doses for prolonged periods have been associated with carcinogenic diseases.

Conclusions

The characteristics of temporary maize production have weaknesses that put the harvest at risk for food supply and safety from the production and consumption of this seed. Likewise, the advanced age of the producers threatens the production of corn, since there is a risk of losing empirical knowledge, which could be accelerated due to the low participation of young people in the study region.

On the other hand, the environmental conditions of the warehouses, although they retain optimum temperatures and humidity to preserve the seed, are also precariously conditioned, since they do not meet the minimum health requirements, which is evidenced in the exposure of the product to the inclement conditions. of time and the waste of various animals (dogs, cats, rodents, etc.).

Likewise, the presence of aflatoxins was detected in all samples of stored corn, although at levels that are permissible according to NOM-187-SSA1 / SCFI-2002. These toxins are the result of the interaction of different factors, since the grain can be contaminated in the field or by poor sanitary and storage practices.

Ultimately, the present investigation showed that the main risks that threaten the production of corn in the study regions are the use of agrochemicals and aflatoxins in storage systems. These factors are a threat because of their latent toxicity to family supplies.

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Rol de Contribución	Autor (es)
Conceptualización	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo)

	Hermila Orozco Bolaños (apoyo)
Metodología	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Gerardo Suárez González (apoyo) Hermila Orozco Bolaños (apoyo)
Software	Guillermina García Juárez (principal) Gerardo Suárez González (apoyo) Maricela Hernández Vázquez (apoyo)
Validación	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Hermila Orozco Bolaños (apoyo) Gerardo Suárez González (apoyo)
Análisis Formal	Guillermina García Juárez (principal) Gerardo Suárez González (apoyo) Maricela Hernández Vázquez (apoyo)
Investigación	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Gerardo Suárez González (apoyo) Hermila Orozco Bolaños (apoyo)
Recursos	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Hermila Orozco Bolaños (apoyo)
Curación de datos	Guillermina García Juárez (principal) Gerardo Suárez González (apoyo) Maricela Hernández Vázquez (apoyo)
Escritura - Preparación del borrador original	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Gerardo Suárez González (apoyo) Hermila Orozco Bolaños (apoyo)
Escritura - Revisión y edición	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Gerardo Suárez González (apoyo) Hermila Orozco Bolaños (apoyo)
Visualización	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo) Hermila Orozco Bolaños (apoyo)
Supervisión	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo)
Administración de Proyectos	Guillermina García Juárez (principal) Maricela Hernández Vázquez apoyo)
Adquisición de fondos	Guillermina García Juárez (principal) Maricela Hernández Vázquez (apoyo)