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Traditional maize post-harvest management practices amongst smallholder farmers in Guatemala

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ABSTRACT

Much of the maize that is produced in Guatemala is planted, harvested and handled via subsistence-oriented agricultural practices, strongly connected to Mayan heritage. This post-harvest assessment study was done to characterize the current practices used in the region of Huehuetenango, Guatemala, in order to identify the different grain handling practices in the region as well as possible factors contributing to post-harvest losses of maize. A total of 280 families representing 14 rural communities were surveyed through interviews. Survey revealed that most (88%) of interviewed farmers prefer to dry the maize cobs after harvest by laying them in stacks exposed to direct sunlight. After drying, harvested maize is stored until consumption along with purchased maize kernels from the market. Among storage practices, 62% of surveyed families store the maize as shelled kernels; while 38% store it on cobs. When storing shelled maize, bags are the preferred containers among 81% of farmers, while only 14% use metal silos. Among farmers who stored maize on cobs, 74% use the *tapanco* as the preferred storage structure. Forty-one percent of farmers indicated storing the maize for at least 4 months. During the storage time, 61% of farmers perform grain quality checks once a week. Moreover, 65% perform pest control during storage; however, in most cases, the control is not preventive but corrective. For 49% of farmers, the main cause of loss between harvest and consumption is the mishandling of grain moisture, leading to insect and fungal infestation. With this data, it was possible to identify diverse maize harvesting, drying, storage and consumption practices within the studied communities. Understanding the traditional post-harvest practices will help better design intervention steps to improve these practices and to increase food security and food safety for smallholder farmers in the Guatemalan Highlands.

1. Introduction

The majority of agriculture in the highlands of Guatemala is devoted to the culture of maize and beans. Wheat, squash and a few other vegetables are also grown on small farms (Williams and Menegazzo, 1988) mostly due to their attractive market value (Hamilton, 2005; Reardon et al., 2009), but also for being less labor intensive (Immink and Alarcon, 1993). Of these, maize is considered a staple crop for Guatemala's population (Argueta, 2013), even more so for low income households (Van Etten and Fuentes, 2004). In this country, this crop averages an annual production of 1.7 million metric tons (USDA, 2014). More than half of Guatemala's maize is consumed as tortillas, at approximately 170 kg per capita per year (Kenneth and Kiple, 2000; Schmidt et al., 2012). Besides this, several other Guatemalan dishes are based largely on maize, which also happens to be a very susceptible commodity to fungal contamination (Appell et al., 2009).

Fungi thrive in relatively low moisture environments compared with bacteria, which make grains, and more specifically maize, a perfect niche. This is further exacerbated when poor handling and storage conditions allow access to pests and/or promote moisture migration to the seed. Given that certain fungi can produce harmful compounds to humans and other animals, their presence becomes of concern. The toxicity of these compounds, known as mycotoxins,

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is dependent on several parameters such as dosage, chemical structure, length of exposure, and affected organism, among others (Bryła et al., 2013; Cornell University, 2015). Depending upon the dose, the effects of food-borne mycotoxins can be acute, with symptoms of severe illness appearing rapidly. At lower doses fungal toxins show long term chronic effects on health, including the induction of cancer, and immune deficiency (FAO, 2016). Previous work in the lowlands of Guatemala indicate an incidence of mainly fumonisin but also aflatoxin, mycotoxins produced by fungi in the genera *Fusarium* and *Aspergillus*, respectively, acting synergistically or individually. Health problems attributed to these mycotoxicoses in the region include neural tube defects, stunting and hepatocellular carcinoma (Torres et al., 2015, 2007).

Previous findings by the International Maize and Wheat Improvement Center, known by its Spanish acronym as CIMMYT, revealed that for a significant part of the western highlands of Guatemala food production is of subsistence; agricultural assets are generally very small and rural properties are highly fragmented (CIMMYT, 1981). It is in such rural regions where people have limited economic resources that a larger maize consumption is more noticeable (Torres et al., 2007), therefore even low levels of mycotoxin contamination could pose a substantial health risk to this population. Moreover, the lack of financial support results in limited technical knowledge and tools (Immink and Alarcon, 1993) for appropriate grain handling practices, among which proper storage and drying equipment stand out. Many of the farmers in the highlands of Guatemala use rudimentary and empirical techniques where little technology is involved. Consequently the present work aims to evaluate such conditions to better understand their potential role and impact on maize quality and safety.

This study took place in Huehuetenango, Guatemala. This department lies in the northwestern corner of Guatemala. Geographically, it is bounded to the north and west by Mexico, to the east by the department of Quiché and to the southeast by the department of Totonicapán. This region is largely mountainous with a total area of approximately 7500 square kilometers (~2900 mi^2) (Baepler, 2016). More specifically, the townships of Chiantla and Todos Santos Cuchumatán, of the Huehuetenango department were subject to investigation.

Understanding the different traditional maize-handling practices performed in the Highlands of Guatemala will help elucidate their potential influence on the class of maize produced, sold or consumed, as well as its safety and shelf-life. Additionally, data would guide the choice of better intervention steps, if necessary, to decrease smallholder farmers' maize spoilage and post-harvest losses, and ultimately increase the food security and safety of the region.

2. Materials and methods

2.1. Sampling method

Households located in communities or settlements known as landscapes, villages, towns, cities, etc. from Todos Santos and Chiantla were randomly selected. The sample size (n = 267 households) obtained from community conglomerates was determined using the following equation (Chow et al., 2007):

$$n = \frac{\left(Z_{\alpha/2}\right)^2 * p(1-p)}{d^2}$$

Where,

- $Z_{\alpha/2}$: 1.962, confidence level at 95%. Two-tail test.
- p: ratio, 0.50. The variance of the indicators measured as a proportion reaches a maximum point as they approach 0.50, ensuring an adequate sample size.
- 1−p: probability of failure. Complement of the event.
- d: accuracy or acceptable error limit. In this case 6% (0.06).

Possible losses of study subjects for various reasons (data loss, abandonment, no answer) was also taken into account with a sample increase. The adjusted sample size ($n_{adj} = 280$) was determined as follows (Pérez et al., 2013):

$$n_{adj} = n\left(\frac{1}{1-R}\right)$$

Where,

- R: proportion of expected losses, 5% (0.05) is expected.

These 280 households were distributed between Chiantla (35.7%) and Todos Santos (64.3%). Although Todos Santos' population and terrain are the smaller of the two, the selection of the sample is proportionately greater due to its variations in altitude.

2.2. Community selection

The communities were selected based on their altitude and maize production chain (producers or purchasers). Communities were divided in three groups depending upon the altitude: type C: altitude from sea level until 1500 masl (meters above sea level), type B: between 1500 and 2700 masl, and type A: above 2700 masl.

Farmers having land available to plant and harvest maize (producers) were designated “Chain 1” farmers; while farmers who didn't have land and thus rely on purchasing maize were identified as “Chain 2” farmers. With 20 families per community, 14 communities were covered in this study: 9 from Todos Santos, 5 from Chiantla.

2.3. Surveying process

Two hundred and eighty families from the 14 communities of Todos Santos and Chiantla, townships of Huehuetenango in Guatemala, were surveyed between May and August 2014. The survey consisted of 80 questions in order to get acquainted with household composition, practices related to agriculture and grain handling, community organization, level of technical education, hygiene and health. Only results related to maize agriculture, harvest, grain handling and storage are included in the present article. Unless otherwise noted, farmers' answers to questions were referred to the 2013–2014 harvest season.

Before the actual interviewing of the different households, the interviewers selected for the survey were properly trained. At the end of such trainings, interviewers demonstrated having knowledge and understanding of the study objectives, mastering the survey instrument to be used (i.e. ballots), having an impartial interview technique, knowing the areas the study comprised, logistics and contact with community, route plan, among others. In addition, interviewers spent a day of work in the field to validate their skills and mastery over the instruments.

This validation was performed with people in the community of Taluca from the township of Chiantla. This community was not selected to participate in the study, however it showed similar characteristics to those that were. Several consultations between post-harvest scientists and SHARE (Self Help And Resource Exchange), the NGO providing field personnel, resulted in the refined survey instrument and procedures to be followed.

3. Results and discussion

3.1. Farmers and land tenure

Almost the entire sample (99.6%) mentioned having land available for agriculture. However 90.0% of respondents own the land while 10.0% rent or borrow. Of this, 82% of land owners and 15.7% of renters/borrowers expressed using the land specifically for planting maize. Much of the decision to plant or buy maize to meet household demands was associated with maize availability, the economic capacity for hiring labor and buying fertilizer, as well as the support from government or social programs (Washington Office on Latin America, 2013).

Even though land is available, at times it is not necessarily enough and consequently farmers rent or borrow additional land. Table 1 provides a breakdown of land tenure and usage based on land size. Of this, the percentage of farms in Chain 1 that own land was similar for those in altitudes A and B (>92%). Also regarding Chain 1, altitude A showed the highest percentage (26.3%) of farms that counted with rented land to be used for farming. For Chain 2, households located at altitude C reported not owning, borrowing or renting any land; while altitude A had a rate of land ownership of 39.3%, followed by altitude B with 59.3% (individual altitude data not shown). Overall it is a subsistence agriculture (CIMMYT, 1981) with no abundant revenues, thus neither food security nor capital growth are maintained.

Even though the main purpose of farming in this region is home consumption, data indicates that there is not enough land available to reach the household demand. This could be related to weather conditions that affect production, as well as the average size of families. Of the surveyed households, 62.1% were comprised of 6 or more members. This directly affects the food availability of every household, as their low economic means may prevent all members from having access to nutritious food, and therefore they may not have a balanced diet.

Moreover, farmers have shown a positive attitude towards planting higher value crops for profit as they are aware of the opportunity to use their land for both economic and cultural heritage benefits. From an economic point of view, the proportion of land dedicated to maize agriculture may suffer a decrease in the future. Farmers from other regions of the Highlands of Guatemala are starting to be open to the idea of including non-conventional commodities such as mini-squashes and berries in their land. These products can result in higher profit compared to traditional commodities (Hamilton, 2005).

3.2. Maize planting and harvest

Although most (80.4%) farmers produce maize, as this traditional agricultural practice is an important component of their identity (Hamilton, 2005; Van Etten and Fuentes, 2004), all of the surveyed farmers buy additional maize for home consumption confirming an insufficient production for the annual household demand.

Table 1
Land tenure and usage according to size in Todos Santos and Chiantla, Huehuetenango, Guatemala.

Land size (cuerda[a])	Percentage of land		
	Used for planting (%)	Owned (%)	Rented (%)
1–3	27.1	29.6	30.6
4–8	34.5	34.0	50.0
>9	38.4	36.4	19.4

[a] 1 cuerda = 20*20 m.

Regarding the seed usage, 95% of the farmers reported using native (*criolla*) seeds. The most outstanding varieties used by the farms in the region included: annual white maize, short white maize, white maize, *San Lorenzo* yellow, dog's teeth, native yellow, pinto maize, *Salqueño* maize, black maize, *Sarquilito* and native *Chucuy* maize. These are the common names used by the farmers to describe their heirloom seeds which have been used for years, and have been selected for their best features (i.e. kernel uniformity in size, large cob size, resistance to pest damage/mold, etc.). More information on selection criteria will be presented.

A majority (66.8%) of farmers believe *criolla* seeds (mostly flint varieties) have higher yields than commercial (dent) varieties, and 38.4% find *criolla* seeds superior in pest and disease resistance. This latter advantage is likely due to the maize composition. Unlike their dented counterparts, flint corn has shown to be more impervious to insect damage as it possesses a hard outer layer to protect the soft endosperm (Suleiman et al., 2015). Additionally, inhabitants of the region prefer some native varieties while preparing specific food products (Van Etten, 2006). For instance, farmers in the community of San Antonio Las Nubes mentioned that *Diente de Perro* (dog's teeth) is used for tortillas while *Salpor* is used for baking bread.

Regarding the availability of materials and tools to plant maize, nearly all of the farmers (99.5%) reported having tools (hoe, shovel, etc.) to work the land during planting and harvest. Also, 94.0% use fertilizers, 11.0% improved seeds, and 61.5% native seeds. Only 3.3% reported having access to irrigation equipment. It is important to mention that in the region of study, located in the north-western region of Guatemala, there are generally two alternate planting seasons based on elevation. The "January cycle", which is from January to October, usually is performed in the elevated areas or higher plateau at approximately 2600 masl. This planting is done leveraging the naturally occurring moisture in this region. The "May cycle" from May to December, in the lower regions, is dependent upon the rainy season. Accordingly, for those places where rain is not frequent, yields can be compromised due to poor plant development if not enough water is available in the growing stage of the plant life cycle. Conversely, those regions with excessive rainfall lead to high moisture levels in the field causing ear rot, premature sprouting, and mold growth. Furthermore, once harvested, maize from these high moisture level areas may take longer to dry exposing the maize to the environment for a longer period, thus making it more vulnerable to pests and fungi.

3.3. Traditional knowledge on maize handling

A large portion of the sample (92.9%) reported having a minimum of five years of experience managing their land; most have done it throughout their lives. The maize is destined for self-consumption (98.9%) and only a small fraction is sold to neighbors or local markets.

A practice called *dobla* (to fold the stem of the maize plant to interrupt the transport of water and nutrients, accelerating drying) is done when the grain is fully formed and is no longer milky, which happens around 85–90 days after planting (Instituto de Ciencia y Tecnología Agrícolas ICTA, 2014). This is practiced by 33% of the interviewees. The majority of farmers follow very specific conditions such as a period of prolonged rain to establish the harvesting time. For those who perform *dobla*, some will ascertain the proper time to perform it based on the color of the tassel (10.4%) or the leaves (26.4%), and a smaller fraction rely on the nail test (4.4%). This last method consists of evaluating the grain hardness by puncturing a kernel with a fingernail.

Regarding the *tapisca* (harvest), farmers follow specific practices or combination of practices inherited through generations.

Similarly as for *dobla*, some farmers proceed to harvest based on one or more of these: color of the tassel or leaves; the nail or mouth test which consists of evaluating the maize hardness by either nail pressing or biting a kernel, respectively; between 25 and 30 days (Instituto de Ciencia y Tecnología Agrícolas ICTA, 2014) after *dobla*; based on rain pattern; and/or specifically after every December 1st. The most popular practices are harvesting based on the color of the leaves (27.2%) or 25–30 days after *dobla* (42.9%). In some cases, farmers will notice that the evaluated cob is *sazón* (ready), and proceed to collect the entire maize harvest at once rather than let it partially rot or germinate on the fields. In some cases, varying from farm to farm, maize growers have set dates for harvest based on relevant calendar dates (either Catholic or civil calendar). As an example, some farmers in Todos Santos prefer to perform their harvest after the *All Saints' Day*, celebrated on November 1st.

Seventy six percent of the respondents perform harvest entirely by hand while others use tools such as machetes or knifes to facilitate the task. Some farmers in San Antonio las Nubes mentioned that the harvest is performed during a full moon, as it results in much harder grain and is more resistant to pest attack (Bravo Martinez, 2009) during storage. Field observations revealed that most farmers didn't perform tillage on their farms. Even though no-till has advantages such as erosion control (Chulze et al., 2000), it can also significantly increase the relative frequency of mycotoxigenic and spoilage fungi present in the field, thus increasing the chances of contamination.

3.4. Maize damage

Upon harvest, 98.4% of farmers said they see some type of damage either on the maize plant or on the cob; in most cases both kinds of damage were observed. Fig. 1 shows the different sources of damage identified by farmers. It is known that weather during the growing and harvesting season influences maize damage to some extent due to contamination with fungi (Cotty and Jaime-García, 2007), which was the most frequently reported type of damage (~68%). It is important to note that farmers only reported fungal damage when it was evident (e.g. pink slurry, white mold), but even when not noticeable, fungal contamination may have already occurred while they take this maize as visually safe (Martinez et al., 1970).

Other sources of damage reported were animal damage (namely squirrels, opossums and mice) followed by bird damage, worms and diseases. All of these ultimately result in entry points for fungi, explaining the reported dominance of fungal damage in the region.

3.5. Selection and drying practices

Selection is performed either for storage and consumption purposes, or for later use as seeds for the next production cycle. Interviews revealed that this is performed based on several characteristics of the kernels, depending upon the usage and maize variety. Farmers may use one or more of the following practices: color of the cob (used by 77.2%), size of the kernel (52.17%), proper amount of kernels per cob (48.37%), kernels without visible damage or stains (31.52%) and/or absence of fungi. Other less frequent but important features mentioned were cob weight and the combination of weight and color. For some farmers seed selection takes place in the field during harvest (37.36%) while others do it prior to drying (37.91%) or when the maize is being stored (28.02%.). *Mulco* maize is a term used to refer to maize damaged by fungi, insects or rodents. The fate of this maize will be discussed in later sections.

The majority of interviewed farmers (93.5%) who produce maize reported performing some type of drying practice before storage. Out of that fraction, 3.5% dry the maize in the whole plant (*milpa*), before cutting the cob. The rest remove the cob from the plant and then proceed to dry it. In this group, 88.4% of farmers indicated sun-drying the ears before storing, while 10.5% said they place the ears directly in the *tapanco*. Although farmers said they can combine different techniques (i.e. sun-drying and drying in *tapanco*), no one mentioned the use of mechanical dryers. Alternatively, some farmers dry the maize after the shelling process. Once shelled, 10.0% of the interviewees place the maize on nylon sheets followed by sun-drying. Among all farmers the most common practice is to dry the ears after being harvested. Some farmers in San José las Flores reported to have *tapancos* above their living quarters with tin roofs. They use this as a space for drying maize over a period of approximately one month (November to December), and then place it in wooden boxes located inside the house, in silos or bags. This practice is due to the rainy conditions around harvesting in this area, which makes it impossible to do sun-drying. Although it is considered a promising post-harvest storage technology to maintain maize quality, there is a potential issue for farmers who store their maize in metal silos. Conditions such as temperature fluctuations and improper drying prior to storage (i.e. maize with unsafe moisture levels), common in this tropical country, could promote condensation on the storage vessel inner walls, rewetting the grain in specific areas and thus creating hot spots for fungi and an accompanying intensification in mycotoxin occurrence.

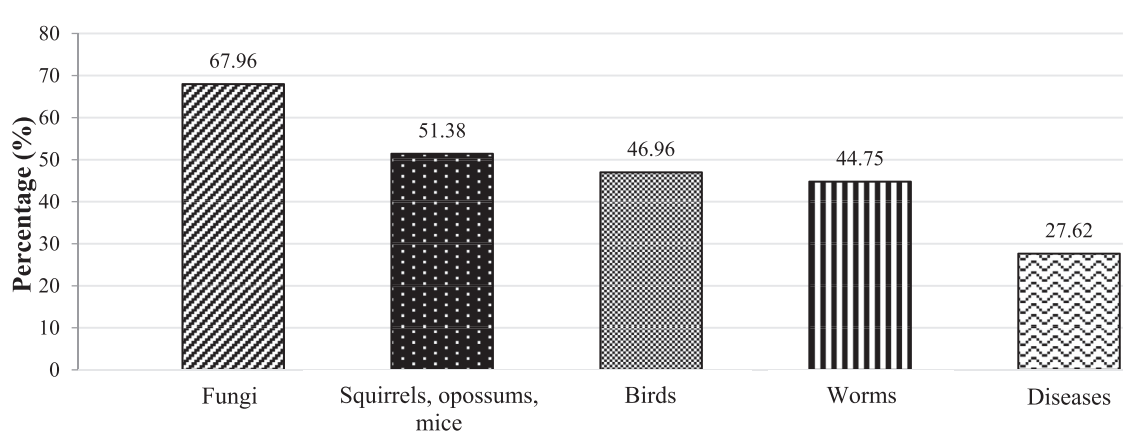

Fig. 1. Farmers' observations regarding maize damage during harvesting period.

3.6. Storage and grain usage practices

Decision regarding grain readiness for storage is based on traditional practices that include tactile or finger-nail test (32%), mouth test (16.9%), and a combination of sound and visual observation (45.4%). A small number of producers (~3%) have a surplus in their production out of which 1.7% sell maize in the local market or to families in the community. This small proportion is partially due to lack of economic means to have more land available to plant maize. Additionally, smallholder farmers do not have technical knowledge or assistance to meet the rapidly changing and stringent food quality standards (Hamilton, 2005) for commerce. It was observed that when maize was sold it was usually on market days: Wednesdays, Thursdays, and Sundays.

It was found that 74% of the farmers prefer to use the *tapanco* as storage for ears. This practice allows farmers to protect it from the elements. If the maize's husk is intact, it encloses the kernels and protects them against insects, but it also limits the exchange of moisture between the kernels and the environment (Sole, 1994). It was observed that some families rely on the greenhouse effect of the *tapanco* letting the heat of the roof finish the drying process. This is of concern as maize that is potentially not properly dried is stored, in some instances for years, with no adequate aeration or moisture control. This can lead to mold growth and potentially be a risk factor to future harvests placed in this space, resulting in the same issue as previously described for silo usage.

To a lesser degree, maize is stored in *mancuerna* (23%) which consists of partially husking the ears and using the remaining husks to hang them from the main beams in the porch area. This practice is associated with the cobs selected to be used as seeds for the next crop cycle. For some farmers the practice of *mancuerna* is more dependent on the variety, as field observations revealed that the *salpor* and other native varieties are preferably dried via this method. The remaining farmers (3%) utilize *troja* as a mean of storage. This is a self-standing box structure built from scrap wood and wire. This last storage method is becoming less popular compared to the others previously mentioned; tendency indicated that it may disappear in the future. Some of the storage methods described are pictured in Fig. 2.

Farmers that buy maize, or shell it upon drying, prefer to store it in bags (81%) made from polypropylene. For Chain 1, this practice was more common in altitudes A (84.2%) and B (80.5%), than in altitude C (67.3%). The use of bags is more widespread in the township of Todos Santos (64%) than in Chiantla (46%). Among farmers that buy maize the practice of using the original package (bag) as a storage container is popular due to its convenience.

When the use of metal silos by the surveyed farmers was evaluated, mostly farmers from Chain 1 altitudes B (23.1%) and C (14.2%) showed interest in the use of this technology for maize storage. Farmers from Chain 2 showed little interest in metal silos (11.5% of altitude A and 12.5% of altitude C). Overall, out of the 14% of respondents who use silos, 79% indicated using the *pastilla* (pill) of a phosphine or phosphamine salt for pest control. Field observations, however, revealed that the method of implementation is not precise as farmers add either insufficient or excess amounts of it, being unaware of possible biological (i.e. prevailing pests) or chemical contamination of their crops.

Regarding the length of storage, 41% of respondents indicated storing maize for 4 months or more (Fig. 3), followed by 30% who store their corn for 1 month, 19% for 3 months and 10% for 2 months. According to visits during the study it was observed that some families may buy maize that is sufficient for only a week or one month since their income does not allow them to purchase large quantities of grain. This could explain why almost one third of respondents store their maize for less than one month.

3.7. Storage management

In both Chiantla and Todos Santos townships, the practice of cleaning the storage site was evident (98%). Of this, 98% indicated that they clean the storage location before placing the freshly harvested or purchased maize. Eight percent clean the storage location each month and 2% every two months. The practice of cleaning the storage site consists of sweeping the *tapanco* or cleaning the wooden box or silo using a broom and/or cloth. Ninety percent of these farmers perform quality checks before storage and among those, 61.4% check it once a week, 14.1% twice a month, and 5.2% once per month.

Sixty-five percent of farmers perform pest control for grain storage, focusing on rodent, moth and weevil control mostly in the *tapanco*. From these, 53% do it when rodents are observed, 10% do so at the time of storage, and 22% when they observe damage in the kernels, presence of moths, weevils or other insect damage. In most cases, field observations revealed that such control is not preventive but rather corrective. During field visits, farmers mentioned that smoke generated from the kitchen during food preparation helps with pest control for grain placed in the *tapanco*, as this storage assembly is usually above the stove area.

3.8. Post-harvest maize losses

According to farmers, losses after harvest are caused by rodents (18%), rot (32%), due to grain and environmental moisture (12%), fungal damage (5%), birds (5%) and insects (9%). As mentioned before, damage caused by pests contributes to the damage caused by fungi as wounds allow the latter to proliferate (Cotty and Jaime-García, 2007). The rotting of ears and kernels is the most commonly identified reason for loss by farmers. It is important to mention that rot damage, moisture or presence of fungi are related, thus overall 49% of farmers reported losses due to excessive humidity or mishandling of moisture in the grain. In many cases, they first consume the purchased maize leaving the maize they harvested for the end of the season which may aggravate the issue. Table 2 shows post-harvest losses reported by chain and township. A total production of 2237 quintals of maize was reported among surveyed farmers, and from this, 146.7 quintals (6.6%) were lost during storage. Among farmers that purchase maize (Chain 2), a total of 5229 qq were acquired during the period covered by the survey (harvest 2013–2014). From this, a loss of 82 qq was reported representing a 1.5% loss.

Additionally, it is imperative to mention that the reported loss must be understood from the point of view that “damaged” maize may be defined differently among farmers of the Highlands and from a commercially acceptable point of view. In practice, they discard very little maize even when it is damaged. Much maize that is elsewhere considered as damaged is still used in these regions for human or animal consumption, so one can expect that losses reported here may be underestimated.

Overall, this information shows how deficient current grain handling practices are in the region, since maize buyers (i.e. Chain 2) had a considerably lower percentage of losses compared to maize producers: ~1% and ~6%, respectively. This is comparable to other developing countries. In Africa, post-harvest losses associated with maize have been reported to be around 12–36% (Adda et al., 2002; Tefera, 2012). Similarly in Belize rates were of 20–30%, in Brazil 15–40%, in Mexico 10–25%, and in Nicaragua 15–30% (National Academy of Sciences NAS-NAE, 1979).

3.9. Damaged maize usage

Seventy percent of the interviewed households indicated that

Fig. 2. Different storage methods found in Chiantla and Todos Santos. a) Tapanco, b) Cajón (wooden box), c) Metal silo d) Mancuerna.

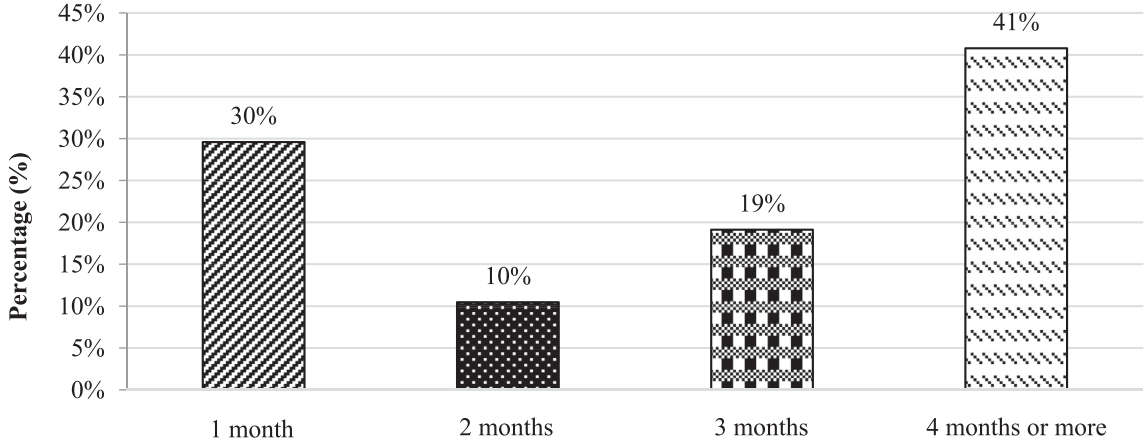

Fig. 3. Maize storage period according to farmers. Graph reflects pattern observed by farmers throughout several seasons and it does not necessarily reflect the last season.

maize that shows any sign of damage is given to animals. Interestingly, although maize is considered damaged, 20% of the families would still consume it. Damaged maize can be either used for human consumption by mixing ("diluting") with sound maize, for animal consumption or eventually discarded; a decision which usually lies with women as field observations and previous research (Hamilton, 2005) in the Highlands of Guatemala revealed. The practice of mixing *mulco* with healthy maize kernels impinges directly on food safety, as the *mulco* portion has more evident pest damage and is likely to be heavily infested by microorganisms, and possibly by several toxigenic species. This practice is more frequent in Todos Santos than in Chiantla since the waste of maize in Todos

Table 2
Perceived post-harvest losses in the region of study by chain and township.

Township	Chain	Produced or Purchased maize (qq[a])	Reported loss (qq)	Percentage of loss (%)
Todos Santos	1	1197	82.5	6.9
	2	3282	48.4	1.4
Chiantla	1	1040	64.2	6.2
	2	2247	33.1	1.4

[a] 1 quintal = 100 lb.

Table 3
Maize production in Chiantla and Todos Santos, season 2014–2015.

Harvest range (qq)	Percentage of farmers (%)
5–10	71.2
15–20	15.8
>25	13.0

Table 4
Estimated average maize daily consumption in farms from Chiantla and Todos Santos, Huehuetenango, Guatemala.

Maize consumption (g/person/day)	Group average consumption ±SD (g/person/day)	Percentage (%)
<600	387.6 ± 127.6	52.9
600–1000	757.4 ± 118.7	35.4
>1000	1329.4 ± 309.3	11.8

Santos is not considered socially acceptable. Culturally it is said that "People who waste or throw the maize kernels may develop rash on their skin" which would be "punishment from God" for the sin of wasting maize. Overall, 83% of farmers buy maize to replace what has gone bad. However, in Todos Santos, one quarter of all respondents indicated not replacing maize even when damage is evident. In Chiantla, 94% of farmers reported having replaced the damaged maize.

3.10. Maize and food security

According to the survey results, compared to previous seasons, maize production in 2014 fell by 20–60% due to a prolonged drought in the area under study, putting at risk the food availability for farmers in 2015. During this study 67.4% of farmers reported having harvested less than the previous year. Table 3 summarizes the yield of 2014–2015 harvest. During 2014 the prolonged drought began in July 18th and ended on August 14th. This drought affected the proper development of plants and consequently the maize yield.

For Guatemalan families maize is a staple food. Seventy-four percent of respondents indicated that they need more than 5 lb of maize per day to feed their family. However in some cases the need was between 12 and 15 pounds. When townships were compared, the study found that in Chiantla 86% of the families need more than 5 lb per day, while in Todos Santos this pattern occurs for 66% of respondents. Because of their dependence on maize, the region's food insecurity is intensified during erratic weather patterns, such as the irregular rainfall and extremely long heat wave observed during the 2014 season.

3.11. Maize availability

Table 4 reveals estimated maize consumption quantities for the region of study, where 52.9% of respondents consume less than 600 g/person/day (=1.32 lb/person/day) with an overall mean of 388 g/person/day (=0.85 lb/person/day) for this group. The remaining respondents consume more than 600 g/person/day, with some consuming as much as ~3000 g/person/day. Eighty-four percent of respondents indicated having maize in storage at the time of data collection; quantities shown in Fig. 4. Basing family maize requirements on a consumption of approximately 317.5–453.6 g/person/day (=0.7–1.0 lb/person/day) (Bressani, 1990; CIMMYT, 1981), the majority of farmers would not have enough maize to support their families beyond 2 months, coinciding with previous findings (López, 2002). Twenty-five percent of respondents reported having more than 500 lb of maize in storage, however after asking if the current stored maize would be sufficient to meet the food needs of the family until the next harvest, more than half of this fraction (67%) indicated that it was not enough, showing signs of food insecurity.

Data collected in the present study provided a better understanding of the agricultural practices followed in the Western Highlands of Guatemala. Because some of these practices may be less than desirable in safeguarding the integrity of the crop, investigations related to grain moisture and mycotoxin levels should follow. The results of this research will be key in determining the design of those surveys to account for the most important types of storage, drying methods, and practices adopted in the region. This will lead to a more robust sampling plan for such study. Moreover,

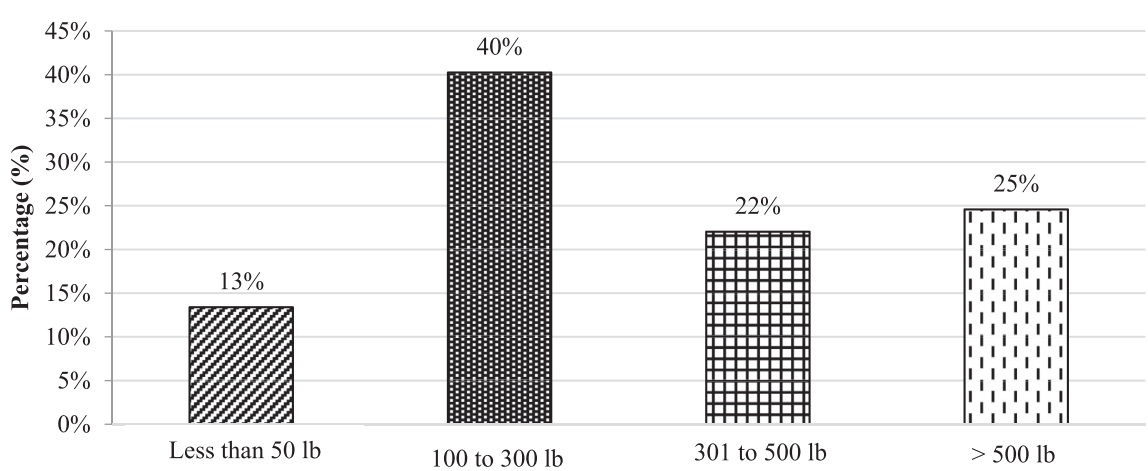

Fig. 4. Available maize in storage among farmers surveyed (Season, 2014–2015).

the results of this survey can be used to understand the potential acceptance of future interventions. For example, by knowing that in certain locations (altitudes) farmers are familiar or used to certain technologies (i.e. metal silos), even if they do not currently use them, indicate that the introduction of improved, but similar technologies, may be better accepted by that population. Therefore, these findings could be used to guide the choice of interventions to be applied in this region. Additionally, based on the results of this survey, it seems that improvement related to grain safety and quality could be achieved by applying mechanical drying, the widespread use of hermetically or semi-hermetically sealed storage, and farmer education.

Conflict of interest

None.

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