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Comparison of the processing and quality of tortillas produced from larger grain borer *Prostephanus truncatus* (Horn.) resistant and susceptible maize genotypes

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A B S T R A C T

The aim of this research was to compare the processing and quality of tortillas produced from two kinds of larger grain borer (LGB) *Prostephanus truncatus* (Horn.) damaged kernels: resistant (IRM) and susceptible (ISM) genotypes. The damaged LGB kernels had significant lower test weight, 1000 kernel weigh and density. The ISM kernels were more negatively affected by insects compared with the IRM counterpart. A significant reduction of 5% in starch was observed in IRM kernels but not in ISM counterparts. Flour acidity and protein increased 8-fold and 5%, respectively parallel to an augmentation of weight grain losses whereas the crude fat content significantly reduced by 29%. Insect damage enhanced the penetration of the hot lime solution into the starchy endosperm. Insect infested kernels which lost 10% and 20% of their weight required 34% and 42% less lime-cooking time compared to sound kernels. The 10% and 20% insect-damaged kernels lost 15 and 23% of their solids during storage and tortilla processing, respectively. Finally, LGB damaged kernels reduced substantially the tortilla quality in terms of color.

1. Introduction

Maize tortillas are considered the most important staple food for the Mexican population. In Mexico, tortillas are consumed by 94% of the population and represent 47% of the average caloric intake and the industrial processing 1% of the gross national product (SAGARPA, 2002). Tortillas and related products, such as tortilla and corn chips, gruels, tamales, among others, are obtained from three different manufacturing processes: traditional, commercial fresh-masa and dry-masa flour.

Tortilla production efficiency and yield is affected by dry matter losses (DML) incurred during nixtamalization. The most relevant processing parameters that affect DML are lime-concentration and cooking time, steeping time, degree of agitation, and extent of nixtamal washing (Pflugfelder et al., 1988; Sahai et al., 2000). These losses also are affected by major grain properties. It is well known that endosperm texture or hardness, kernel size and ease of pericarp removal are important traits that affect cooking and DML (Serna-Saldivar et al., 1993). In fact, the use of grain lots with high incidence of stress cracks, broken and damaged kernels increase up to 12% the DML (Jackson et al., 1988). A significant proportion of the damage kernel categories are due to insect pests. This is a major constraint in grain lots because their presence is normed by regulatory agencies. The Mexican official normativity for white and yellow maize specifies that no more than 3% and 10% of total damage kernels are allowed in order to categorize premium (Mexico-1) and low quality corns (Mexico-4), respectively (SAGARPA, 2002). Furthermore, the maximum allowable amount of insect fragments used as a sanitary indicator is 1 fragment/g of tortilla (SAGARPA, 2002). There are not enough food quality control measurements for the use of damage kernels in small tortilla factories that manufacture more than 60% of the Mexican domestic production (Mery et al., 2010).

Recent investigations have documented that grain damage and postharvest losses of maize due to storage insect pests such as the larger grain borer (LGB), *Prostephanus truncatus* (Horn.) (Coleoptera: Bostrichidae), are an increasingly important constraint of food security worldwide (Borgemeister et al., 2003; FAO, 2009). *Prostephanus truncatus* is a woodborer and an invasive post-

Abbreviations: DML, dry matter losses; IRM, insect resistance maize; ISM, insect susceptible maize; GWL, grain weight losses; LGB, larger grain borer; RH, relative humidity.

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harvest insect native from Mesoamerica that has acquired the status of a serious pest in the Americas, Asia and Africa (Tigar et al., 1994; Kumar, 2002). Studies in Africa and Latin America have shown that subsistence farmers in highlands, tropical and subtropical agro-ecologies experienced 10–45% maize losses and *P. truncatus* is responsible of 10–80% of damage in storage (Tigar et al., 1994; Bergvinson and García-Lara, 2004). Besides of the relevant dry matter losses, the quality of the damaged kernels for tortilla production is downgraded. Fortunately, several landraces and improved maize varieties available in the market have been characterized as resistant to *P. truncatus* (Arnason et al., 1994; Kumar, 2002). Kernels of resistant varieties have been characterized for biophysical, biochemical and genetic characteristics (Bergvinson and García-Lara, 2004), and contribute to reduction in losses throughout storage because resistant varieties suffer only 13–50% as much grain weight loss compared to susceptible counterparts (Bergvinson and García-Lara, 2004; García-Lara et al., 2004).

Most of maize produced in Mexico is commercialized in formal and informal local markets (Keleman and Hellin, 2009) having unknown levels of grain damage. Thus, the tortilla industry uses local maize which sometimes contains damaged grains due to postharvest pests such as *P. truncatus*, *Sitophilus zeamais*, *Sitotroga cerealella*, among other secondary postharvest pests. Needless to say, the tortilla industry in some instances incorporates damaged kernels into the manufacturing process, however there is not information about the impact in nixtamalization process, cooking time and DML and tortilla quality when a fraction of the kernels used in the manufacturing are infested with *P. truncatus*. The aim of this research was to compare the processing characteristics and quality of tortillas produced from resistant and susceptible maize genotypes that were purposely damaged with *P. truncatus* in two different levels.

2. Material and methods

2.1. Maize germplasm

Genotypes of maize used in this research were kindly donated by International Maize and Wheat Improvement Center-Global Maize Program. The two genotypes were selected based on previous reports of postharvest insect resistance (García-Lara et al., 2004). The genealogy of these materials included the improved recurrent selection Population-84 C3, Pop84c3, (IRM) and one single cross hybrid CML244X346 (ISM), which served as control. The ISM is the type of grain preferred and commonly used by the tortilla industry in highland zones of Mexico (Miranda et al., 2013). Both maize varieties were grown and harvested during 2009. Crops were managed following the agronomic practices: fertilization with a total of 250 U of N, 60 of P and 30 of K per hectare, pest management and weed control were performed using standard practices in the region. After harvesting and threshing, the shelled corn samples were stored at 4 °C for until use.

2.2. Insect pest culture

Insect rearing was maintained using the methods previously described by Bergvinson and García-Lara (2011). Briefly, *P. truncatus* was reared in 0.5 L glass jars with vented lids that were filled with 400 g of equilibrated maize (30 d at 27 ± 1 °C, 70 ± 5% of RH) covered with 10 g of maize flour and infested with 250 unsexed adults. Progeny were collected after 6–8 weeks. Adults were obtained by sieving maize containing grain damage in excess of 50%.

2.3. Treatments and evaluation of susceptibility parameters

For insect bioassays, three independent treatments were performed under laboratory conditions. The treatments were a) maize kernels infested with *P. truncatus* until the grain weight losses (GWL) reached 10%, b) 20% GWL and c) control without infestation. All experiments were conducted under controlled conditions in a bioclimatic room (27 ± 1 °C, 70 ± 5% of RH and 12:12 L:D). Four replicates for each treatment were performed for both IRM and ISM varieties. Each replicate was conducted on 500 g of maize that was allowed to equilibrate (12% moisture) for 3 weeks prior to infestation with *P. truncatus*. Moisture kernel content was assayed using a gravimetric method AACC (2000) 44-15A. Each jar was infested with 150 unsexed adults of *P. truncatus* (0–7 days-old). Susceptibility parameters were determined every 30 days until the GWL reached either 10% or 20% for each genotype. A nest of mesh sieves (#6 and #18, USA, Standard Testing Sieve, VWR, USA) and a collection pan was used to separate damaged kernels, *P. truncatus* adults, and flour. Grain weight loss, flour production (FP), and number of live *P. truncatus* adults were recorded according with methods described by Kumar (2002) and modified by Bergvinson and García-Lara (2011).

2.4. Physical properties

Kernel test weight was determined using the Winchester Bushel Meter (Seedburo Equip. Co., Chicago IL) according to method 14–40 of the AACC (2000). Thousand-kernel weight by weighing 100 randomly selected kernels and multiplying by 10. Flotation index (FI) was expressed as a percentage of floating kernels on an aqueous solution of sodium nitrate with a specific weight of 1.25 g/cm^3 at 35 °C. Color parameters L*, a*, b*, Chroma ($(a^2 + b^2)^{1/2}$) and Hue (arctangent (b/a)) for whole kernel samples were obtained with a colorimeter (Minolta CR-300, Osaka, Japan). The pericarp, endosperm, germ and tip cap were manually dissected after soaking 50 g kernels in 100 mL water for 2 min and dried in an oven set at 60 °C before weighing.

2.5. Nutrimental and biochemical analyses

Moisture content was assayed using a gravimetric method AACC (2000) 44-15A. Total starch was calculated using a commercially kit (Method 76-13, AACC, 2000; Megazyme International, Wicklow, Ireland). Protein (N*6.25) was determined using the micro-Kjeldhal method 46-13 whereas crude fiber, fat, and ash were assayed according to methods 32-10, 30-20 and 08-01, respectively (AACC, 2000). Flour acidity was obtained with the 939.05 Official Fat Acidity Method for Grains (AOAC, 1980).

2.6. Lime-cooking optimization

The lime-cooking properties of the two different sound maize genotypes and GWL counterparts were determined according to the nylon bag procedure described by Serna-Saldivar et al. (1993). The procedure consists of lime-cooking kernels contained in perforated nylon bags for three different times (0, 20 and 40 min) followed by 16 h steeping. The lime-cooked corn kernels were washed with tap water and then weighed before and after drying in order to calculate nixtamal moisture and DML. Linear regression equations were calculated to predict optimum cooking and DML. Optimum cooking was considered the time sufficient to increase nixtamal moisture to 48% after 16 h steeping.

2.7. Production of table tortillas

One kilogram of each type of maize was lime-cooked at 95–100 °C for the predetermined optimum cooking time with 3 L of