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Effects of Harvest Time on Quality of Stored Maize (*Zea mays* L.) in the Southern Part of Ghana

Efectos del tiempo de cosecha sobre la calidad del maíz almacenado (*Zea mays* L.) en la parte sur de Ghana

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Abstract

In Ghana, most smallholder maize farmers delay harvesting of their crops in an attempt to achieve optimum moisture content levels necessary for safe storage. Late harvesting may cause a hike in insect attacks and fungal contaminations, leading to alterations in nutrient composition of grains. This study examined the effects of harvest time and storage form on quality of maize. Maize was grown and harvested from 36 plots, with each plot measuring 3m x 3m. Planting of maize was done during the major and minor seasons (April – August, 2020 and September – December, 2020) respectively. Moisture content of maize before storage was determined as 12.50 % to 12.85 % (major season) and 11.90 % to 12.48% (minor season). Harvesting was done at three stages (E = Early harvest, M = Mid harvest and L = Late harvest) and maize was stored for 90 days in three different ways (D = Dehusked, H = Husked and S = Shelled). Data was subjected to Analysis of variance (ANOVA) using Sisvar version 5.6. Mid harvest dehusked maize had the highest final starch content (69.28 %) while Early harvest husked maize had the highest protein content (7.22 %). Ash content of maize from the various treatments ranged from 3.50% to 5.39 % (initial) and 3.03 % to 4.13 % (final), the difference was significant ($p<0.05$). Late harvest husked maize (LHH) recorded 35 % more initial ash as compared to EHS. Aflatoxin level was highest on Late harvest dehusked maize (60.70 ppb). Nutrient and aflatoxin levels of maize were significantly affected by harvest time. Encouraging farmers to adopt a better approach to harvesting, drying and storage of maize can reduce crop losses and ensure food security.

Key words: *aflatoxins, harvest time, maize, nutrient composition*

Resumen

En Ghana, la mayoría de los pequeños productores de maíz retrasan la cosecha de sus cultivos en un intento por alcanzar los niveles óptimos de contenido de humedad necesarios para un almacenamiento seguro. La cosecha tardía puede causar un aumento en los ataques de insectos y contaminaciones por hongos, lo que lleva a alteraciones en la composición de nutrientes de los granos. Este estudio examinó los efectos del tiempo de cosecha y la forma de almacenamiento sobre la calidad del maíz. El maíz se cultivó y cosechó en 36

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parcelas, cada una de las cuales medía 3 m x 3 m. La siembra de maíz se realizó durante las temporadas mayor y menor (abril – agosto de 2020 y septiembre – diciembre de 2020) respectivamente. El contenido de humedad del maíz antes del almacenamiento se determinó entre 12.50 % y 12.85 % (temporada mayor) y 11.90 % y 12.48 % (temporada menor). La cosecha se realizó en tres etapas (E = Cosecha Temprana, M = Cosecha Media y L = Cosecha Tardía) y el maíz se almacenó durante 90 días de tres formas diferentes; D = Mazorca con vainas, H = Mazorca sin vainas y S = Desgranado. Los datos se sometieron a Análisis de varianza (ANOVA) utilizando Sisvar versión 5.6. El maíz descascarillado de cosecha media tuvo el mayor contenido final de almidón (69.28 %), mientras que el maíz descascarillado de cosecha temprana tuvo el mayor contenido de proteína (7.22 %). El contenido de cenizas del maíz de los distintos tratamientos osciló entre 3.50 % y 5.39 % (inicial) y 3.03 % y 4.13 % (final), las diferencias fueron significativas ($p < 0.05$). El maíz descascarillado de cosecha tardía (LHH) registró un 35 % más de ceniza inicial en comparación con el EHS. El nivel de aflatoxinas fue más alto en el maíz descascarillado de cosecha tardía (60.70 ppb). Los niveles de nutrientes y aflatoxinas del maíz se vieron afectados significativamente por el tiempo de cosecha. Alentar a los agricultores a adoptar un mejor enfoque para la cosecha, el secado y el almacenamiento del maíz puede reducir las pérdidas de cultivos y garantizar la seguridad alimentaria.

Palabras clave: *aflatoxina, tiempo de cosecha, maíz, composición de nutrientes*

Introduction

Maize (*Zea mays* L.) is one of the principal crops grown globally for food, feed and industrial purposes (Revilla et al., 2022). It is considered as a major food security crop in sub-Saharan Africa (Awata et al., 2019). In Ghana, maize is a major staple crop and it is grown across a wide range of agro – ecological zones. Some major factors that hinder maize production in Ghana include inadequate soil nutrient levels, drought, diseases and insect pest infestations (Adu et al., 2014). Insects pests are the major cause of maize losses during storage (Kumar & Kalita, 2017). Maize grains exposed to insect attacks have high tendencies of being infected by mycotoxin-producing fungi (Opoku et al., 2023). Mycotoxin contamination affects maize quality and consequently has several human and animal health implications as well. (Darfour & Rosentrater, 2022). In some parts of Africa, when maize plants attain physiological maturity, some farmers strip the leaves, cut off the tops of the maize crop and then leave the cobs to dry on the field. Other farmers choose to harvest early so that they can make room for the next crop (Chegere, 2018). Harvest time and storage form play a vital role in fungal contamination. Besides insect pest attacks, fungal contamination has been associated with most post-harvest losses (Mutungi et al., 2019). In Ghana, most farmers harvest their maize at different times and store them in several ways. An awareness and understanding of the effects of harvest time and storage form on quality of maize can help farmers to make the right choices with regard to harvest and post – harvest handling practices. Food and nutrition security can be promoted as well through the implementation of appropriate interventions. Therefore, the objectives of this study were to: 1) examine the effects of harvest time on the nutritional content of stored maize 2) determine the effects of harvest time on aflatoxin and fumonisin levels of stored maize.

Materials and methods

The study area

Planting for both major and minor seasons was carried out at Ntribuoho (6^{0}46'60"N and 1^{0}40'0"W) in the Afigya Kwabre district in Ashanti region, Ghana. The Afigya-Kwabre District is located in the semi-deciduous forest zone.

Planting

Planting of maize was done in April, 2020 (major season) and September, 2020 (minor season).A total land area of 19 x 23 m^2 was divided into 36 plots. Each plot measured 3m x 3m with 1m between plots. Inter - row and intra – row spacings of 0.7m and 0.4m were used respectively. The maize variety used in planting was 'Obaatanpa', which was obtained from the Crop Research Institute at Fumesua in the Ashanti region of Ghana. Obatanpa is the most widely cultivated maize variety in Ghana (Poku et al., 2018). It has a maturity period of 105 days to 110 days. Obatanpa is a white dent open pollinated variety (OPV) quality protein maize (QPM) that is great for improved nutrition and human health. By 2005, Obatanpa was sown on more than half of Ghana's maize area (International Maize and Wheat Improvement Center [CIMMYT], 2013). Three maize seeds were planted per hill. Two weeks after emergence, they were thinned to two seedlings per hill. Weeding was carried out when needed. Porselen Emamectin Benzoate 5 % was applied for the control of fall army worms. NPK 15:15:15 was applied five (5) days after emergence and during tasselling.

Treatment and Experimental Design

There were a total of nine treatments and each treatment had four replications. A randomized complete block design (RCBD) was used on the field whereas a completely randomized design (CRD) was used in the laboratory. The Treatments were; cobs harvested early, dried, de-husked (EHD), cobs harvested early, dried, stored with husk (EHH), cobs harvested early, dried, shelled before storage (EHS), cobs harvested at physiological maturity period, dried, de-husked (MHD), cobs harvested at physiological maturity period, stored with husk (MHH), cobs harvested at physiological maturity period, shelled before storage (MHS), cobs harvested late, dried, de-husked (LHD), cobs harvested late, dried, stored with husk (LHH) and cobs harvested late, dried, shelled before storage (LHS).

Harvesting, drying and storage

Harvesting took place in August/September, 2020 (major season) and December/January, 2020 (minor season). Maize cobs from each treatment were harvested at three different times (15, 17 and 19 weeks after germination). Cobs were harvested from plants located on the inner rows of each plot to eliminate border errors. At harvest and before storage, cobs from each treatment were randomly selected and shelled. A John Deere moisture meter manufactured by Agra-Tronix™ (Moisture Check Plus™), (SW08120, Moline, IL, USA) was then used to determine the moisture content (MC). Initial grain moisture content was 14.35 % to 15.28 % (major season) and 14.20 % to 14.63 % (minor season) while final moisture content of grains was 12.50 % to 12.85 % (major season) and 11.90 % to 12.48 % (minor season). For each time of harvest, cobs were dried with their husks intact for two weeks to achieve an optimum MC before cobs were then transferred to the laboratory for storage. After drying, 10 cobs were randomly selected from each treatment. For treatments 'de-husked' and 'shelled', husks were removed while husks were maintained for treatment 'husked'. Maize was shelled by hand for treatment 'shelled'. Maize was kept in 10-liter plastic buckets. The buckets were covered with muslin cloths and secured with jute strings to promote aeration as well as prevent insects from escaping.

Laboratory Experiment

The experiment was carried out at the insectary of the Faculty of Agriculture, KNUST, Ghana (6.6754^0 N, 1.5667^0 W). For each season, the storage period lasted for 90 days (September-November, 2020 (major) and February-April, 2021 (minor)). Data was taken on initial and final nutritional content of maize. The initial and final aflatoxin and fumonisin levels of maize were also determined.

Aflatoxin and Fumonisin analyses

Analysis was done using the AgraStrip® Total Aflatoxin Quantitative Test WATEX® and AgraStrip® Total Fumonisin Quantitative Test WATEX® by Romer Labs® (Danso et al., 2017; Manu et al., 2018).

Procedure and sample extraction

A representative sample was obtained and grounded using a Romer series II® Mill so that 95 % will pass through a 20-mesh screen. Sub-sample portion was then thoroughly mixed. 10 g of ground sample was weighed into one side of a Filter Whirl-Pak® bag. An extraction buffer bag was added to the corn sample in the Filter Whirl-Pak® Bag. The extraction buffer bag dissolved completely during the extraction process. 30 mL of distilled, deionized or bottled water was added and the Filter Whirl-Pak® bag was closed. Sample was vigorously shaken for 2 minutes at room temperature and allowed to settle for 2 minutes.

Extract dilution and test procedure
The sample extract was diluted with dilution buffer in a ratio of 1:21. Extract was pipetted from side of filter bag that is opposite of the sample. If the sample had a large foam head, the bag was tilted for easier access to the supernatant. 100 µL of diluted sample extract was added into a microwell, and the content in each microwell was thoroughly mixed by pipetting it up and down 4 times. One test strip was inserted into one microwell. The cover was placed back into the heat block to cover the microwells and test strips. The test strip was allowed to develop color for 3 minutes. The heat block cover was lifted and placed on the top of the heat block. The end of the strip test was wiped on an absorbent paper and inserted into the strip holder/tray for reading. The AgraVision Reader was used to immediately read the strip and interpret results.

Proximate Analysis
Maize samples were milled to obtain maize grit samples of particle size of 250 microns (~60 Mesh) using a laboratory mill. Samples were heaped in the center of a sample cup and levelled to ensure it is compact with all air pockets removed. It is then tightly locked with cup cover and inserted in a calibrated DICKY-JOHN INSTALAB 700® NIR analyzer. Samples were then analyzed with a 'WHOLE MAIZE' analytical matrix and batch coded for traceability purposes. Proximate analysis of individual samples was conducted in triplicates with their respective results displayed and recorded.

Statistical Analysis
Data was entered in Microsoft Excel (2016). Shapiro Wilk's test was used to check for normality of the data. Analysis of variance (ANOVA) was applied to the data through Sisvar version 5.6 (Ferreira, 2008). Treatment means were compared using the Scott-Knot test at 5 % probability.

Results and Discussion

Effect of treatment on Aflatoxin and Fumonisin levels of maize

Late harvest de – husked maize (LHD), LHH and LHS showed the highest initial and final aflatoxin levels. Conversely, EHD, EHH and EHS produced the least aflatoxin levels after storage (final aflatoxin) (Figure 1).

Fumonisin levels showed similar trend to that of initial aflatoxin. Late harvest de-husked maize (LHD), LHH and LHS recorded the highest statistically while no significant differences existed between the other treatments (Figure 2).

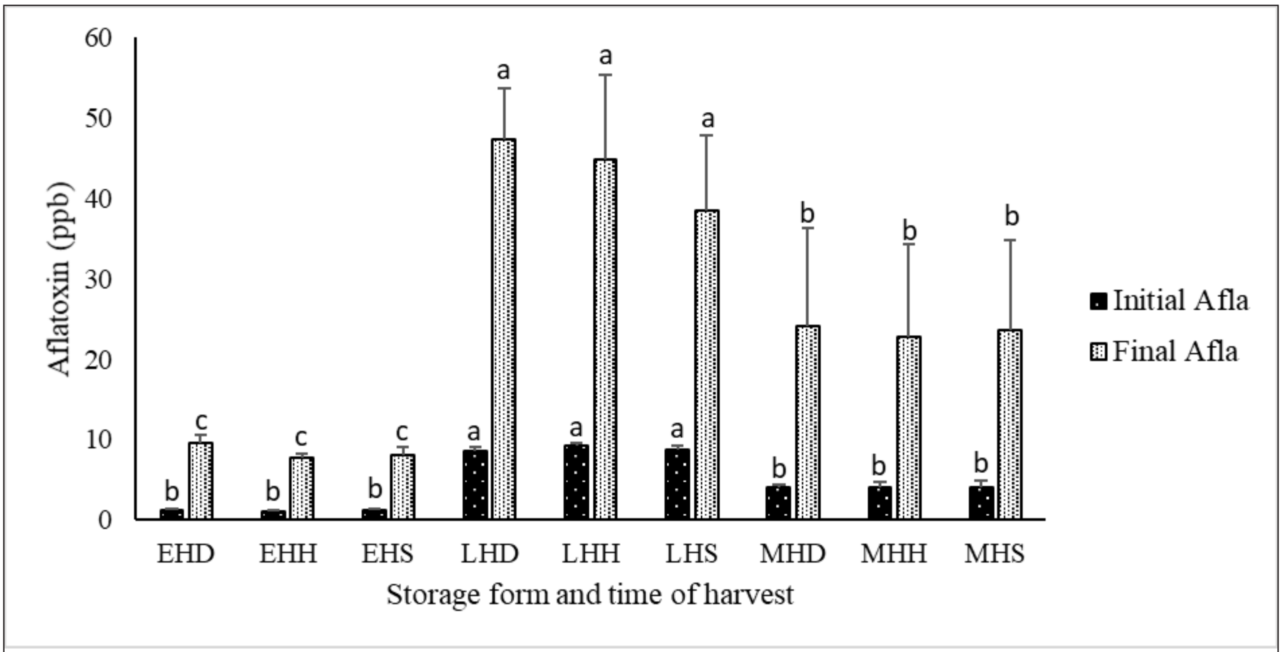

Figure 1. Effect of storage form and time of harvest on Aflatoxin levels of maize.

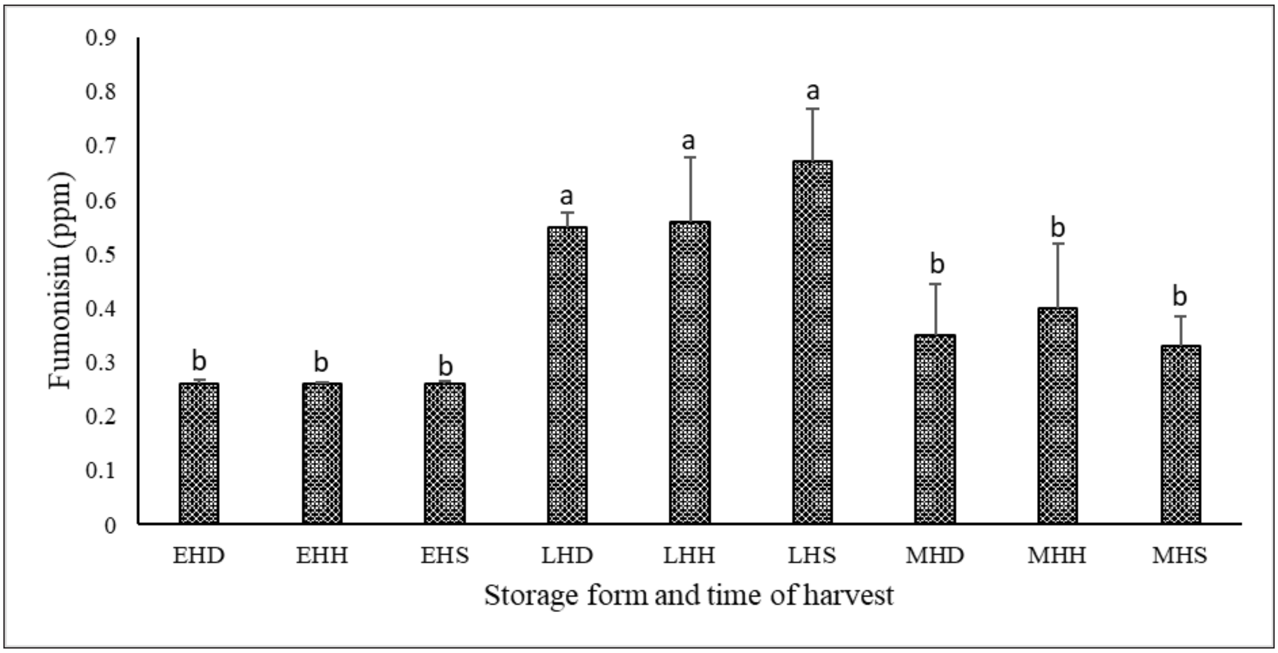

Figure 2. Effect of storage form and time of harvest on fumonisin levels.

Treatment effect on nutritional content

Starch (%)

Late harvest shelled maize (LHS) recorded the largest initial starch though it was not statistically different from LHD, LHH, MHD, MHH and MHS (Figure). Mid harvest dehusked maize (MHD) recorded 3% more final starch than EHS which recorded the least (Figure 3).

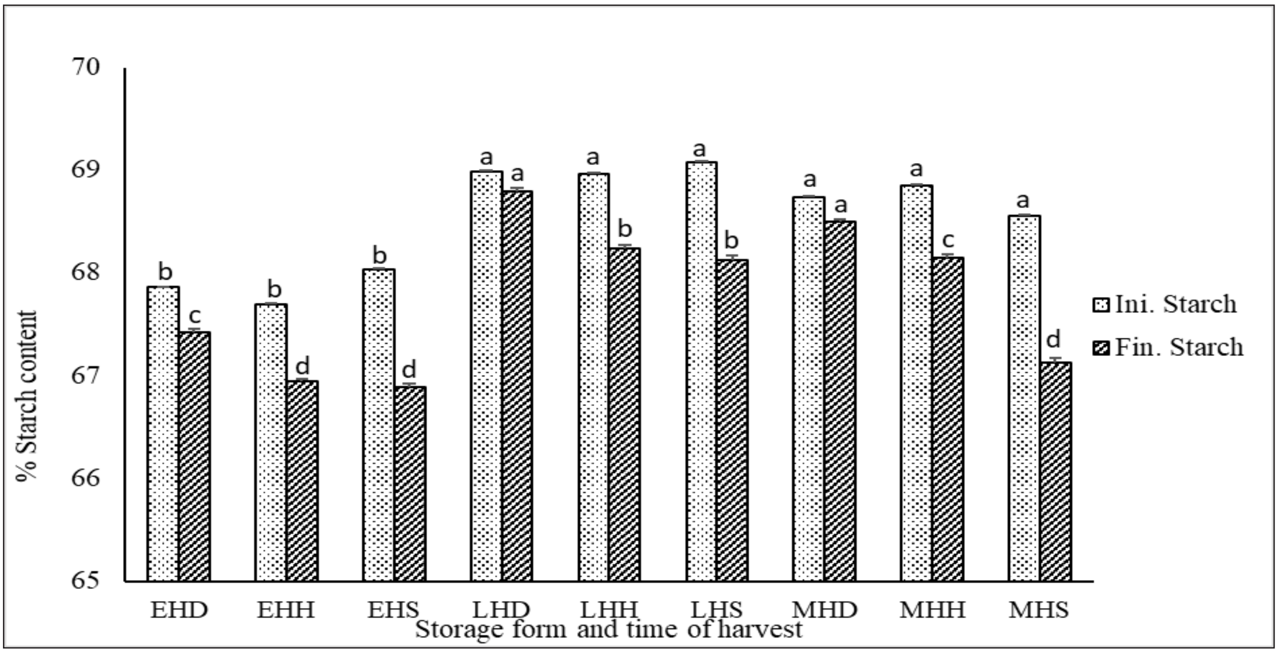

Figure 3 . Treatment effect on starch content of maize before and after storage.

Note: **EHD**: cobs harvested early, dried, dehusked; **EHH**: cobs harvested early, dried, stored with husk; **EHS**: cobs harvested early, dried, shelled before storage; **LHD**: cobs harvested late, dried, dehusked; **LHH**: cobs harvested late, dried, stored with husk; **LHS**: cobs harvested late, dried, shelled before storage; **MHD**: cobs harvested at physiological maturity period, dried, dehusked; **MHH**: cobs harvested at physiological maturity period, stored with husk; **MHS**: cobs harvested at physiological maturity period, dried, shelled before storage. Means followed by the same letter are not significantly different (P>0.05)

Protein (%)

There were significant differences between treatments for both initial and final protein. Late harvest husked maize (LHH), LHD and LHS were statistically lower than EHD, EHH and EHS for initial protein. However, MHD and MHH showed the least final protein whiles EHH, EHS and LHS recorded the highest statistically (Figure 3).

Ash (%)

Ash content of maize from the various treatments ranged from 3.50 % to 5.39 % (initial) and 3.03 % to 4.13 % (final); the difference was significant (P<0.05). Late harvest husked maize (LHH) recorded 35 % more initial ash as compared to EHS. However, the former was not statistically different from LHD and LHS (Figure 3). Generally, final ash decreased compared to initial ash. Early harvest dehusked maize (EHD) and EHH showed statistically smaller final ash compared to the other treatments (Figure 4).

Fat (%)

Treatments did not exhibit significant differences (p>0.05) with regard to initial fat (Figure 4). However, treatments showed significant differences (p<0.05) with regard to final fat. Early harvest shelled maize (EHS), LHD, LHH, LHS and MHS were statistically larger than EHD, EHH, MHD and MHH generally (Figure 5).

Effect of treatment and season on aflatoxin and fumonisin levels of maize

The results did not show significant interaction between the treatments and the seasons with regard to aflatoxin (Table 1). Late harvest de-husked maize (LHH) recorded 87 % more aflatoxin before storage (initial) as compared to EHH in the major season while LHS produced 93 % more aflatoxin than EHH in the minor season (Table 1). Level of aflatoxin after storage (final) was highest (60.70 ppb) on LHD in the major season though not significantly different from LHH. Early harvest de-husked maize (EHH) produced the least aflatoxin levels (6.66 ppb) as compared to LHS (60.72 ppb) in the minor season. However, no significant differences were observed between EHH, EHS and EHD (Table 1). For fumonisin levels in the major season, significant differences existed between treatments. However, there were no significant differences in the minor season. Late harvest de-husked maize (LHD), LHH and LHS were significantly different from the other treatments in the major season (Table 1).

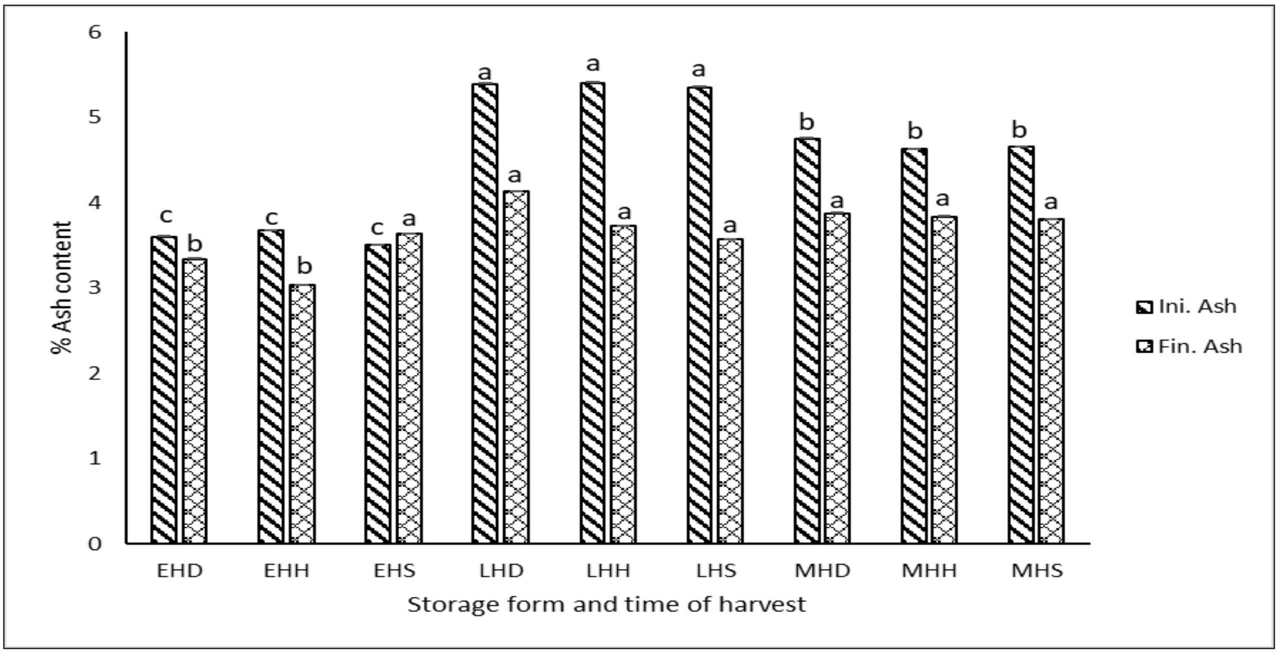

Figure 4. Treatment effect on ash content of maize before and after storage.

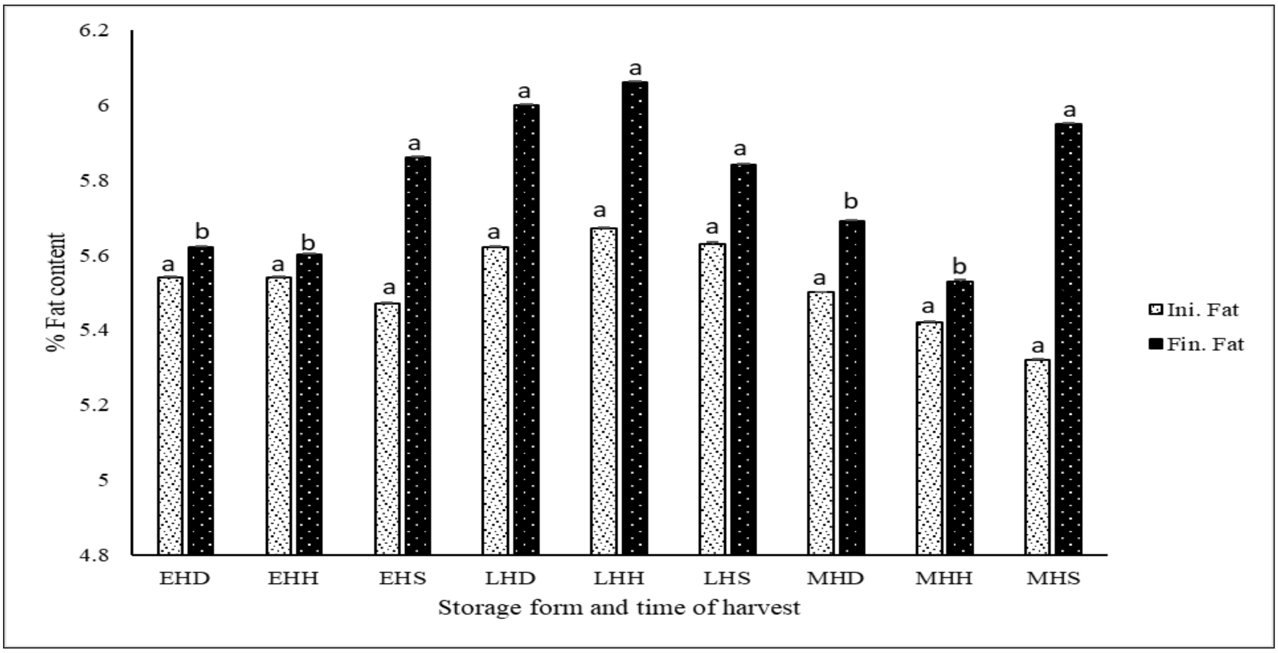

Figure 5. Treatment effect on fat content of maize before and after storage

Table 1. Initial Aflatoxin (IAf (ppb), Final Aflatoxin (IAf (ppb) and Fumonisin (F (ppm) levels of maize treatment. Mean number (±SE).

Treatments	Season	IAf (ppb)	FAf (ppb)	F (ppm)
EHD	Major	$1.52±0.46^{cA}$	$10.08±1.87^{bA}$	$0.27±0.01^{bA}$
EHH		$1.40±0.52^{cA}$	$8.81±0.50^{bA}$	$0.28±0.01^{bA}$
EHS		$1.64±0.51^{cA}$	$7.83±0.87^{bA}$	$0.26±0.01^{bA}$
LHD		$9.74±2.86^{aA}$	$60.70±33.5^{aA}$	$0.57±0.08^{aA}$
LHH		$10.56±1.95^{aA}$	$57.18±10.34^{aA}$	$0.63±0.13^{aA}$
LHS		$8.85±0.99^{aA}$	$16.05±5.08^{bB}$	$0.72±0.28^{aA}$
MHD		$3.97±0.56^{bA}$	$19.31±12.08^{bA}$	$0.31±0.05^{bA}$
MHH		$3.93±0.36^{bA}$	$16.22±3.89^{bA}$	$0.38±0.07^{bA}$
MHS		$4.16±0.68^{bA}$	$10.94±0.82^{bA}$	$0.30±0.04^{bA}$
EHD	Minor	$0.84±0.50^{cA}$	$8.97±3.75^{bA}$	$0.25±0.00^{aA}$
EHH		$0.64±0.38^{cA}$	$6.66±1.48^{bA}$	$0.25±0.00^{aA}$
EHS		$0.81±0.82^{cA}$	$8.28±4.70^{bA}$	$0.26±0.03^{aA}$
LHD		$7.45±1.10^{aB}$	$33.98±27.40^{aA}$	$0.52±0.31^{aA}$
LHH		$7.80±0.86^{aB}$	$32.27±44.30^{aA}$	$0.48±0.47^{aA}$
LHS		$8.79±1.54^{aA}$	$60.72±37.90^{aA}$	$0.62±0.33^{aA}$
MHD		$4.14±1.45^{bA}$	$28.89±38.10^{aA}$	$0.39±0.27^{aA}$
MHH		$4.16±1.88^{bA}$	$29.37±44.6^{aA}$	$0.43±0.35^{aA}$
MHS		$4.40±1.70^{bA}$	$36.28±18.11^{aA}$	$0.36±0.09^{aA}$
P-values				
T		*0.00001*	*0.0016*	*0.0003*
S		*0.0155*	*0.4262*	*0.7032*
*T * S*		*0.1839*	*0.0636*	*0.9730*

From the results of the study, late harvested maize showed the largest initial aflatoxin levels in both seasons with LHH and LHD recording significantly larger values in the major season. Aflatoxin infestation levels are usually higher during the rainy season due to higher relative humidity and increase in insect damage. Delay in harvest was found to enhance the contamination of maize by aflatoxin, fumonisin and zearalenones in Uganda (Kaaya et al., 2005). Aflatoxin levels ranged from 1.40 ppb to 10.56 ppb and 0.81 ppb to 8.79 ppb in the major and minor seasons respectively. Results obtained from this study agree with Kaaya et al. (2005) who also found aflatoxin levels <20 ppb at harvest.

Aflatoxin levels in maize were found to be higher after storage. According to Massomo et al. (2020), contamination of maize by aflatoxins continues as crops grow in the field, after they have matured and during the storage period. Although no differences were found between the seasons, levels were significantly higher in late harvest in the major season except LHS. However, no differences existed between late and mid-harvested maize in the minor season.

Even though insect populations were smaller in the minor season, higher levels of aflatoxins were observed after storage. According to Enyiukwu et al. (2014), factors that increase the risk of cereals being contaminated by aflatoxins include grain MC, insect pest attack, relative humidity, temperature and toxigenic *Aspergillus* spp. Results from this study showed significant increase in aflatoxin levels above the threshold concentration of <15 ppb recommended by the Ghana Standard Authority (Ghana Standard Authority [GSA], 2013) in mid- and late-harvested maize compared to early harvest.

Aflatoxins may lead to a repressed immune system, malnutrition, growth retardation and liver cancer in humans (Benkerroum, 2020). Apart from human health, aflatoxins induce negative impacts on food security and economical, political and social aspects of humanity (Pickova et al., 2021). Fumonisin levels in all treatments after storage were lower than the 4 ppm threshold stated by the Ghana Standard Authority (GSA, 2013). Although no significant differences were obtained, late harvested maize recorded the highest levels of fumonisin in both the major and minor seasons.

Effects of treatment and season on nutritional content of maize

Protein

All treatments showed significant differences ($p<0.05$) between seasons with regard to final protein except EHH and MHS, which were not significantly different (Table 2). Season and time of harvest affected initial (before storage) protein composition of maize. Early harvest dehusked maize (EHD), EHH and EHS showed statistically larger initial protein in both the major and minor seasons while MHS, MHH and MHD did not show significant differences ($p>0.05$) between the seasons (Table 2). Early harvested maize showed significantly higher protein content in both major and minor seasons as compared to the other treatments. This is contrary to what was observed by Adak et al. (2007), who reported a lower protein content in early harvested maize and a higher protein content in optimal harvested maize.

After the storage period, protein in maize decreased in both major and minor seasons except the late harvested maize. The increase in protein content of late harvested maize could be due to the larger population of insects recovered during storage. According to Stathers et al. (2020), the rate of increase in the number of *Sitophilus zeamais* correlates with an increase in relative protein. Moreover, since more of the *S. zeamais* larvae stay and feed within the grain, their presence may influence the final nutrient composition of the grain.

Starch

Treatments showed higher initial starch in the major as compared to the minor season. However, there were no significant differences between LHD, LHH, LHS and MHD. Final starch also showed significant differences among the treatments in the major than minor season except LHD, LHH and LHS which were higher in the minor as compared to the major season. All the treatments presented significant differences between the seasons (Table 3).

Ash

Most of the treatments recorded significantly higher initial and final ash contents in both seasons except EHD and EHS, which did not show any differences between the seasons with regard to final ash (Table 3).

Fat

All parameters showed significant ($p<0.05$) interaction effect between treatments except in initial and final fat (Table 2). In both seasons, there were no significant differences among treatments with regards to initial fat content. However, EHH, EHS and MHD recorded significant differences between the seasons (Table 2). In the major season, LHH recorded 8 % increase in fat compared to EHD which recorded the least in the major season. Similarly, LHD recorded 12 % more final fat than MHH in the minor season (Table 2).

The results from the study showed that final starch and ash content decreased while fat generally increased. However, there was a decrease in fat in the early and mid-maize harvests in the minor season. Stathers et al. (2020) reported that an increase in population densities of *S. zeamais* were related to a decrease in relative available carbohydrate content. However, the authors found a positive correlation between increasing *S. zeamais* and *P. truncatus* numbers to fat and fiber in maize after storage. Similarly, Tongjura et al. (2010) found variations in fat and a decrease in ash content after infesting maize varieties with *S. zeamais*. In many grains, nutrients are not evenly spread out. Therefore, depending on the part of a grain that is consumed by insects, a 2 % loss as a result of insect attack may cause a disproportional loss in certain nutrients (Stathers et al., 2020).

Table 2. Initial and Final Protein (%) and Fat (%) content of treatments. Mean number (±SE).

Treatments (T)	Season (S)	Initial Protein	Final Protein	Initial Fat	Final Fat
EHD	Major	7.76±0.19^{aB}	6.63±0.33^{bA}	5.40±0.23^{aA}	5.75±0.19^{bA}
EHH		7.78±0.21^{aB}	7.22±0.06^{aA}	5.35±0.22^{aB}	5.86±0.20^{bA}
EHS		7.75±0.25^{aB}	7.17±0.06^{aA}	5.26±0.22^{aB}	6.17±0.06^{aA}
LHD		5.43±0.12^{cB}	6.19±0.14^{cA}	5.57±0.30^{aA}	5.99±0.05^{aA}
LHH		5.46±0.14^{cB}	6.85±0.18^{bA}	5.44±0.30^{aA}	6.28±0.10^{aA}
LHS		5.50±0.08^{cB}	7.01±0.43^{aA}	5.65±0.22^{aA}	6.01±0.09^{aA}
MHD		7.36±0.10^{bA}	6.32±0.02^{cA}	5.30±0.28^{aB}	5.78±0.35^{bA}
MHH		7.41±0.15^{bA}	6.11±0.31^{cA}	5.31±0.21^{aA}	5.79±0.02^{bA}
MHS		7.47±0.09^{bA}	6.72±0.03^{bA}	5.23±0.29^{aA}	6.18±0.28^{bA}
EHD	Minor	8.17±0.20^{aA}	7.58±0.41^{aB}	5.68±0.28^{aA}	5.49±0.18^{bA}
EHH		8.31±0.28^{aA}	7.58±0.27^{aA}	5.74±0.09^{aA}	5.35±0.20^{bB}
EHS		8.29±0.38^{aA}	7.69±0.42^{aB}	5.67±0.23^{aA}	5.56±0.14^{bB}
LHD		7.50±0.20^{bA}	7.55±0.25^{aB}	5.67±0.25^{aA}	6.00±0.34^{aA}
LHH		7.59±0.19^{bA}	7.47±0.11^{aB}	5.50±0.29^{aA}	5.84±0.39^{aB}
LHS		7.34±0.16^{bA}	7.68±0.24^{aB}	5.62±0.28^{aA}	5.67±0.37^{aB}
MHD		7.24±0.22^{bA}	7.01±0.38^{bB}	5.70±0.31^{aA}	5.60±0.28^{bA}
MHH		7.43±0.30^{bA}	7.05±0.26^{bB}	5.53±0.27^{aA}	5.28±0.12^{bB}
MHS		7.37±0.16^{bA}	7.04±0.18^{bA}	5.42±0.23^{aA}	5.72±0.05^{aB}
P-values					
T		*0.00001*	*0.00001*	*0.3383*	*0.00001*
S		*0.00001*	*0.00001*	*0.0005*	*0.00001*
*T * S*		*0.00001*	*0.0067*	*0.6188*	*0.1785*

Note: **EHD***:* cobs harvested early, dried, dehusked; **EHH**: cobs harvested early, dried, stored with husk; **EHS**: cobs harvested early, dried, shelled before storage; **LHD**: cobs harvested late, dried, dehusked; **LHH**: cobs harvested late, dried, stored with husk; **LHS**: cobs harvested late, dried, shelled before storage; **MHD**: cobs harvested at physiological maturity period, dried, dehusked; **MHH**: cobs harvested at physiological maturity period, stored with husk; **MHS**: cobs harvested at physiological maturity period, dried, shelled before storage. Values followed by the same small letters compare treatments within a season, while figures followed by capital letters compare the treatments between different seasons.

Table 3. Initial and final Starch (%) and Ash (%) content of treatments. Mean number (±SE).

Treatments (T)	Season (S)	Initial Starch	Final Starch	Initial Ash	Final Ash
EHD	Major	69.09 ± 0.89^{aA}	68.57 ± 0.17^{bA}	2.84 ± 0.25^{cB}	3.16 ± 0.18^{aA}
EHH		68.82 ± 0.67^{aA}	67.90 ± 0.24^{cA}	2.93 ± 0.26^{cB}	2.29 ± 0.61^{bB}
EHS		69.27 ± 0.64^{aA}	67.69 ± 0.45^{cA}	2.65 ± 0.34^{cB}	3.44 ± 0.26^{aA}
LHD		69.10 ± 0.68^{aA}	68.29 ± 0.74^{cB}	5.02 ± 0.08^{aB}	3.63 ± 0.36^{aB}
LHH		69.02 ± 0.52^{aA}	67.52 ± 0.18^{cB}	5.02 ± 0.11^{aB}	2.81 ± 0.02^{bB}
LHS		69.22 ± 0.28^{aA}	67.75 ± 0.39^{cB}	4.93 ± 0.20^{aB}	2.42 ± 0.15^{bB}
MHD		69.05 ± 0.50^{aA}	69.28 ± 0.05^{aA}	4.29 ± 0.20^{bB}	3.51 ± 0.06^{aB}
MHH		69.28 ± 0.70^{aA}	69.02 ± 0.48^{aA}	4.12 ± 0.44^{bB}	3.35 ± 0.09^{aB}
MHS		69.13 ± 0.61^{aA}	67.47 ± 0.05^{cA}	4.10 ± 0.17^{bB}	3.13 ± 0.02^{aB}
EHD	Minor	66.63 ± 0.54^{bB}	66.28 ± 0.14^{eB}	4.36 ± 0.22^{cA}	3.53 ± 0.46^{bA}
EHH		66.58 ± 0.33^{bB}	66.00 ± 0.28^{eB}	4.42 ± 0.21^{cA}	3.77 ± 0.51^{bA}
EHS		66.79 ± 0.38^{bB}	66.09 ± 0.24^{eB}	4.34 ± 0.14^{cA}	3.82 ± 0.33^{bA}
LHD		68.88 ± 0.34^{aA}	69.32 ± 0.38^{aA}	5.75 ± 0.17^{aA}	4.62 ± 0.24^{aA}
LHH		68.92 ± 0.24^{aA}	68.96 ± 0.17^{aA}	5.78 ± 0.19^{aA}	4.63 ± 0.14^{aA}
LHS		68.93 ± 0.65^{aA}	68.52 ± 0.71^{bA}	5.78 ± 0.23^{aA}	4.72 ± 0.41^{aA}
MHD		68.43 ± 0.16^{aA}	67.72 ± 0.23^{cB}	5.21 ± 0.23^{bA}	4.24 ± 0.62^{aA}
MHH		68.42 ± 0.19^{aB}	67.27 ± 0.17^{dB}	5.15 ± 0.30^{bA}	4.30 ± 0.06^{aA}
MHS		67.98 ± 0.48^{aB}	66.79 ± 0.66^{dB}	5.21 ± 0.39^{bA}	4.47 ± 0.20^{aA}
P-values					
T		*0.00001*	*0.00001*	*0.00001*	*0.00001*
S		*0.00001*	*0.00001*	*0.00001*	*0.00001*
*T * S*		*0.00001*	*0.00001*	*0.0004*	*0.00001*

Note**: EHD***:* cobs harvested early, dried, dehusked; **EHH**: cobs harvested early, dried, stored with husk; **EHS**: cobs harvested early, dried, shelled before storage; **LHD**: cobs harvested late, dried, dehusked; **LHH**: cobs harvested late, dried, stored with husk; **LHS**: cobs harvested late, dried, shelled before storage; **MHD**: cobs harvested at physiological maturity period, dried, dehusked; **MHH**: cobs harvested at physiological maturity period, stored with husk; **MHS**: cobs harvested at physiological maturity period, dried, shelled before storage. Values followed by the same small letters compare treatments within a season, while figures followed by capital letters compare the treatments between different seasons.

Conclusions

The study determined the effects of harvest time and storage form on quality of maize. It revealed that nutrient composition, aflatoxin and fumonisin levels of stored maize were significantly affected by time of harvest. Early harvested maize recorded the highest protein content before storage whereas Late harvest maize recorded the highest protein after storage. Late harvest and Mid harvest maize had the highest initial starch content. After storage, ash content was found to be low in Early harvest maize. Late harvest shelled maize recorded the highest final fat content. Initial and final Aflatoxin levels and Fumonisin levels were found to be highest in Late harvest maize.

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Author Contributions

S.G.A: Data collection, data preparation and analysis, manuscript preparation
S.A-B: Study analysis, review and mentorship
B.S.O: Data collection, data preparation and analysis
P.K.B: Supervision, data preparation and review

Conflicts of interest

The signing authors of this research work declare that they have no potential conflict of personal or economic interest with other people or organizations that could unduly influence this manuscript.

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