THE QUALITY STUDY OF TEN GRAIN CORN VARIETIES DURING 2018/2019 HARVESTING SEASON IN MALAYSIA

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ABSTRACT. Recognizing the significance of grain corn as a vital animal feed, the government established a Grain Corn Development Master Plan (2018-2032) in 2016. The primary objective is to mitigate risk and instability of the national livestock industry by aiming to domestically produce 30 % of the country's grain corn requirement, hence reducing dependency on imports. This study aims to evaluate the quality of ten varieties of corn obtained from different locations in Malaysia. Samples were graded and physical properties were evaluated. The study found that the average test weight, total damaged kernels, and BCFM of samples were 51.9 lb/bu, 12.8 %, and 3 % respectively. No heat damage was found in any of the samples. Two samples from corn varieties Pioneer P4546 (Selangor) and GWG 5005 (Sarawak) showed the highest test weight (56 lb/bu) with less BCFM. Almost all (88.2 %) of the corn samples had BCFM levels equal to or below the 3 % maximum allowed for No. 2 grade. The moisture content, protein, oil, and starch in the grain corn samples ranged from 10.8 to 14.4 %, 5.7 to 9.7 %, 3.2 to 4.3 %, and 63.4 to 68.0 % respectively. Aflatoxin levels below the accepted standard of 20 ppb were found. The study found that the quality of ten selected varieties of grain corn harvested between August 2018 and February 2019 met Malaysian Standard Requirement for Animal Feeds in terms of chemical composition and BCFM levels. Additionally, the varieties of grain corn performed moderately in US Grade (No. 3 grade).

Keywords: Grain corn, quality, grades, animal feed, physical properties

INTRODUCTION

Zea mays, also known as maize, is a member of the grass family Poaceae and one of the most diverse plant species. In some regions of the world, including Malaysia, Zea mays or maize is known as corn. Corn is defined as a grain with high germ content that consists of 50 percent or more of whole kernels of shelled dent corn and/or shelled flint corn (Zea mays L.) and may contain not more than ten percent of other grains (FAO, 1994; USDA, 2013). Corn is also an essential staple cereal crop in some less-developed regions and is grown more than any other grain crop (Olga & Tibor, 2017; Scott & Emery, 2016; Nafziger, 2016). In Asia, grain corn is regarded as the second most important cereal crop after rice. Grain corn is used for food, feed, and industrial products, including biodegradable foams, plastics, and adhesives (Scott & Emery, 2016).

The top three corn producers are the United States (348,751,000 metric tons), China (277,200,000 metric tons), and Brazil (125,000,000 metric tons) (Statista, 2023). The United States Department of Agriculture (USDA) estimated that global production of coarse grains will increase by 4.8 million tons to 1,499.3 million tons in 2023–2024 (USDA, 2023). In Malaysia, corn is typically grown in all areas by smallholder enterprises in small land. There was no reported production of commercial grain corn for feed in Malaysia before 2020. Farmers were more interested in planting sweet maize due to its lower production cost and shorter cultivation time (Mohamad Hifzan *et al*., 2019). According to Malaysian Grain and Feed Annual Report 2023, there was very little commercial corn production for feed, even with government subsidies. The production of commercial grain corn was 91,000 metric tons in 2020, 73,600 metric tons in 2021, and 80,360 metric tons in 2022 (DOA, 2022). The production growth of grain corn faces obstacles such as the absence of biotech varieties, competing earning opportunities from alternative crops, and the unpredictable price fluctuations in the grain corn market. These factors collectively hinder the expansion of grain corn production. While the Government of Malaysia has expanded corn farming acreage to counter rising animal feed costs, the lack of commitments from the private sector poses a challenge to the viability of potential projects (Abdul Ghani, 2023).

Generally, grain quality refers to the physical or nonphysical characteristics that constitute the basic nature of an entity (Fox & O'Hare, 2017). In the United States, the official Grain Standard Act was established in 1916. The grain quality in agriculture is defined depending on the use of the grain. Physical factors (moisture content, bulk density, kernel size, kernel hardness, vitreousness, kernel density, and kernel damage), protection factors (fungal infection, mycotoxins, insects and mites and their fragments, foreign material odour, and dust) and compositional factors are described by grain quality (milling yield, oil content, protein content, starch content, and viability) (Jayas & Singh, 2012).

Grain standards play a crucial role in establishing quality and condition controls for commercial purposes. In Malaysia, there is no official Malaysian Grain Standard Act because grain corn production has yet to reach commercial scale. However, there are two (2) standard specifications for cereal grains (maize) prepared by the Working Group on Animal Feeds and Feedstuffs under the authority of the Food and Agricultural Industry Standards Committee: Official US Standards for Grains (1960) and Federal Grain Inspection Service (FGIS) United States Department of Agriculture, Washington DC. The Malaysian Standard specifies the requirements and methods of sampling and testing for cereal grains for use in animal feeds (MS 226:2005) as well as the determination of broken corn and foreign material (BCFM) in animal feeds (MS 1411:1997). The objective of this study is to evaluate the quality of ten selected varieties of grain corn obtained from various locations in Malaysia.

MATERIAL AND METHOD

Sample Collection

Corn varieties used in this study were taken from field trials. A total of ten (10) varieties of CP 801, CP 888, EKS, Pacific 339, Philippine, Pioneer P4546, Syngenta, Dexal 79b Mosanto, GWG 5005, and GWG 888 were obtained from grain corn growing areas in Perak, Kedah, Selangor, and Sarawak for this study (from August 2018 to February 2019). Seventeen (17) samples were obtained by official personnel using official procedures (MS 6497:2005) and approved equipment to get representative samples (1.0 - 1.2 kg). All samples were kept chilled (0 – 5 ˚C) in sealed moisture-proof containers before further analysis.

Test Weight

Test weight per bushel which is the weight per Winchester bushel (2,150.42 cubic inches) was determined using an approved device. The method was done as described by Lee (2013). sealed moisture-proof containers before further analysis.

Determination of Corn Classes, Infested Corn, and Odour Test

Corn classes, infected corn and odour tests were determined using an organoleptic test which was adopted from USDA (2013). About 250 gram portion of BCFM-free corn was used to classify the samples based on the colour characteristics of the kernels. The corn classes were divided into three which are yellow, white, and mixed corn (USDA, 2013). The odour test of grain corn samples was carried out at the time of sampling or on the sample either prior to or after the removal of foreign material. To ensure the accuracy of the odour test, the sample testing was done at room temperature with stirring or agitation if necessary. Corn grains were classified as acceptable or distinct odour (musty, acidic or commercially objectionable). Infested corn is defined as corn that has been infested with live weevils or other live insects that are harmful to stored grain.

Broken Corn and Foreign Material (BCFM)

The BCFM of the grain corn was carried out by the Hand Sieving Method according to USDA (2013). About 1,000 to 1,050 grams were poured onto the centre of the 12/64 round-hole test sieve. The sieve was moved from left to right approximately 10 inches and then returned from right to left with steady motion for 30 times. The materials that passed through the sieve 12/64 were weighed and considered as broken corn. The foreign materials which were other than corn at the bottom and top collection pan (hand pick) were also weighed. The percentage of BC and FM were calculated separately.

Damaged Kernel

Determination of the damaged kernel of grain corn samples was carried out according to procedures described in grain grading procedures (USDA, 2013) using a 250 gram portion of BCFM-free corn. Damaged kernel is defined as kernels and pieces of flaxseed kernels that are badly ground-damaged, badly weather-damaged, diseased, frost-damaged, germ-damaged, heat-damaged, insect-bored, mould-damaged, sprout-damaged, or otherwise materially damaged.

Chemical Composition

The chemical composition of the grain corn samples, namely moisture content, protein, oil, and starch were predicted by NIRS (Foss DS2500, Hilleroed, Denmark) using established calibration by representative samples. About 50 – 100 g of samples were poured into a large cup holder and placed onto a scanning compartment. The measurement mode was based on diffuse reflectance in the near infrared wavelength region of 400 – 2500 nm by silicon (400 - 1100 nm) and lead sulphide (1100 - 2500 nm) detectors.

Aflatoxins Analysis

Total aflatoxin analysis was performed using ELISA test kit protocol by R-Biopharm, Germany. All samples were ground and homogenised using Ultra Centrifugal Mill, Retsch, and passed through 1 mm sieve. About 5 g of ground sample was extracted in 25 ml of methanol 70 %. The extract was filtered through a Whatman filter (No. 1) and 1 ml from the filtered sample was then diluted by 1 ml of deionized water. 50 µl of diluted filtrate per well was used for the ELISA test (Ridascreen Fast; Aflatoxin Total). The optical density was measured at 450 nm using ELISA reader (Tecan IFU Infinite F50, USA). Absorbance percentages were recorded and the calibration curve obtained with standards at different concentrations. The standard range was 0, 1.7, 5, 15, and 45 µg/kg (ppb). The ELISA data and the aflatoxin concentrations for samples were evaluated using software program R-biopharm (Ridasoft win, version 1.78, R-biopharm, Germany). The LOD for the total aflatoxin kit was < 1.7 ppb.

Data Analysis

Data were summarised and analysed using Statistical Package for Social Sciences (SPSS) for Windows, version 26.0 for mean and percentages.

RESULTS AND DISCUSSION

All seventeen samples in this study were yellow corn based on kernel colour (Figure 1). No grain corn was found infested with any live weevils or other live insects. Two (2) samples were classified as having musty odour whereby 88.2 % of 17 samples were classified as having good or acceptable odour. There were absence of stone, glass, concrete/ wreckage, flint and dent, and waxy corn observed in the collected samples.

The results of physical analysis in grain corn from varietal trials using manual methods and USDA grade and the requirements are shown in Table 1 and Table 2 respectively. This study showed that the average test weight of the sample was 51.9 lb/bu (23.6 kg/hl), equal to US No. 3 grade. Two (2) samples, or 11.8 % of the 17 samples, achieved US No.1 grade (56 lbs/bu). The samples were from corn variety Pioneer P4546 (Selangor) and GWG 5005 (Sarawak). This indicates the potential suitability and positive characteristics of these specific corn varieties in accordance with US grading criteria.

The range of total damaged kernels in grain corn samples collected during the 2018/2019 harvest season was 3.2 to 23.4 % with the average of 12.8 % which is below the total damage limit for No. 5 grade.

The observed percentage of damaged kernels can be attributed to several factors including growing conditions, pest and disease management, harvesting techniques, storage conditions, crop variety, farm management practices, and regular monitoring of the crop throughout its growth cycle (Kumar & Kalita 2017; Waqas *et al*., 2021; Yang *et al*., 2023). Only one (1) sample from variety Pacific 339 (Perak), or 5.9 % of 17 samples was indicated below the limit for US No.1 grade (3 %) total damaged kernels.

The notably low percentage of damaged kernels in the Pacific 339 (Perak) corn sample, below the US No. 1 grade limit, is likely attributed to exceptionally favourable growing conditions in the region.

Optimal weather, high-quality soil, and sufficient irrigation likely play key roles in fostering the overall health and resilience of the corn crop, consequently minimising the occurrence of damaged kernels (Waqas *et al*., 2021). There was no heat damage found on any of the samples in this study. Heat damage, according to the USDA method, refers to kernels (corn) that have been materially discoloured by microbial activity, with the dark discoloration extending out of the germ through the sides and into the back of the kernel are damaged.

The presence of heat-damaged kernels in grain corn is generally considered a negative outcome as it can affect nutritional quality, palatability for animals, storage stability, market value, and processing efficiency (Córdova-Noboa *et al.,* 2021; Odjo *et al*., 2015; Dahlke & Drewnoski 2011). Farmers and producers strive to minimise heat damage during cultivation, harvest, and storage to ensure the overall quality of their grain (Kumar & Kalita 2017; Waqas *et al*., 2021).

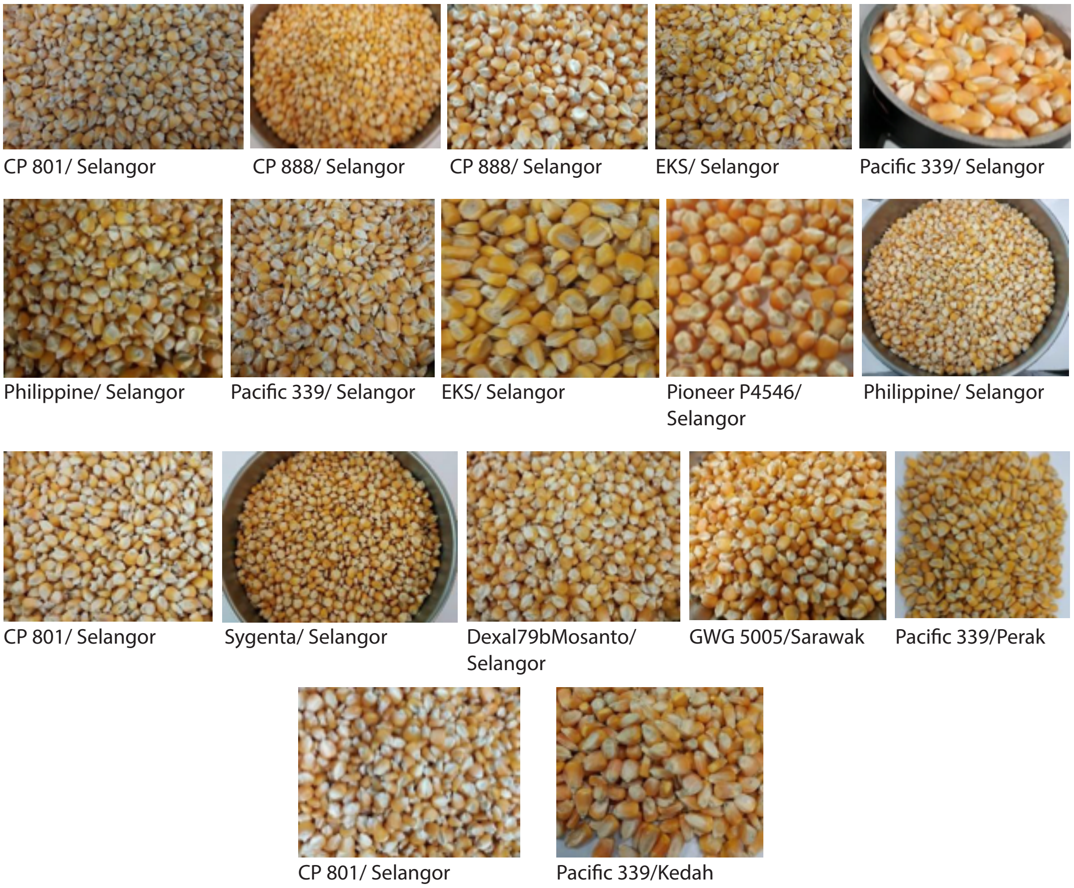

Figure 1. Colour characteristics of the kernels from varietal trial in Malaysia

The average BCFM value was 3.0 % i.e. on the limit of US No. 2 grade with a range between 0.01 to 38.3 %. Only one (1) sample from a variety of Philippine (Selangor) was found to have BCFM % way above the maximum requirement for US No. 5 grade. Out of 17 samples, 88.2 % met the requirement of the US No. 1 grade. These results indicate that there is variability in BCFM values among the samples, the majority meeting the criteria for higher U.S. grades, indicating an overall satisfactory quality level. The sample with BCFM % above the U.S. No. 5 grade requirement may warrant further investigation and attention to understand and address potential quality issues in that specific sample.

Table 1. Physical analysis in grain corn from varietal trial in Malaysia

Variety/location	Test weight per bushel (pounds) lbs/bu	Damaged kernels		Broken corn and foreign materials (percent)
		Heat (percent)	Total (percent)	
CP 801/ Selangor	49.3	Not observed	5.5	0.2
CP 888/ Selangor	50.3	Not observed	10	1.1
CP 888/ Selangor	50.8	Not observed	5.9	0.1
EKS/ Selangor	48.1	Not observed	21.5	1.8
Pacific 339/ Selangor	53.4	Not observed	11.2	0.3
Philippine/ Selangor	51.2	Not observed	20	38.3
Pacific 339/ Selangor	50.7	Not observed	11.5	1
EKS/ Selangor	48.2	Not observed	21.6	0.2
Pioneer P4546/ Selangor	55.7	Not observed	23.4	1.3
Philippine/ Selangor	48.5	Not observed	16.8	5.3
CP 801/ Selangor	51.7	Not observed	6.4	0.7
Sygenta/ Selangor	52.5	Not observed	6.1	0.6
Dexal79bMosanto/ Selangor	54.0	Not observed	9.1	0.4
GWG 5005/Sarawak	56.0	Not observed	15.8	0.1
PACIFIC 339/Perak	54.8	Not observed	3.2	0.01
GWG 888/Perak	52.9	Not observed	6.2	0.2
Pacific 339/Kedah	53.4	Not observed	23.9	0.3
Average values	51.9	Not observed	12.8	3.0

Table 2. USDA Grades and Grade Requirement for Corn

Reference Grade	Min. Test Weight (pounds)	Max heat damage (%)	Max total damage (%)	Max BCFM (%)
US No.1	56	0.1	3	2
US No.2	54	0.2	5	3
US No.3	52	0.5	7	4
US No.4	49	1	10	5
US No.5	46	3	15	7

The results of chemical composition and aflatoxin contamination of grain corn harvested in 2018/2019 season are presented in Table 3. The range of moisture content values was between 10.8 to 14.4 %. One sample from Selangor (variety CP 888) indicated more than 14 % moisture content. The range of moisture content values (10.8 to 14.4 %) indicates variability in the moisture levels of the harvested grain corn. This variability may be influenced by factors such as climate, weather conditions during the growing season, harvesting, and drying practices (Coradi *et al.,* 2020; Amir Syariffuddeen *et al.,* 2018; Weinberg *et al.,* 2008). Higher moisture content at harvest increases the chance of kernel damage during harvesting and drying. This raises concerns about the potential for spoilage, mould growth, and mycotoxin contamination during storage. According to USDA (2013), 14 % or lower moisture content is recommended for storage of more than one year.

The protein ranged from 5.7 to 9.7 %, with the Pacific 339 (Kedah) variety having the highest value. In general, protein values give significant interest to end users. Protein is very important for poultry and livestock feeding because it supplies essential sulphur-containing amino acids and helps to improve feed conversion efficiency. Meanwhile, oil content ranges between 3.2 % to 4.3 %. The variety of Pacific 339 (Kedah) had the highest oil content, at 4.3 %. Oil is an essential component of poultry and livestock rations. It serves as an energy source, enables fat-soluble vitamins to be utilised, and provides certain essential fatty acids. The range of starch values were 63.4 to 68.0 %. Grain corn from Pioneer P4546 (Selangor) had the highest starch content. Starch is an important factor for corn used by wet millers and dry-grind ethanol manufacturers. High starch concentration is often indicative of good kernel growing/filling conditions and reasonably moderate kernel densities.

A total of 15 samples, or 88.2 % of the 17 samples had aflatoxin levels below than 10 ppb. Two (2) samples, or 11.8 % of the 17 samples, showed aflatoxin levels greater than 10 ppb, but less than 20 ppb. The lowest total aflatoxins detected in grain corn was 3.4 ppb, while the highest was 18.7 ppb. This variation could be influenced by factors such as storage conditions, environmental factors, and agricultural practices (Abrehame *et al.,* 2023; Kumar *et al.,* 2021). However, the presence of samples with levels above 10 ppb indicates a need for continued monitoring and potential interventions to mitigate aflatoxin contamination risks in certain batches of grain corn (Umar *et al.,* 2023).

Table 3. Chemical composition and aflatoxin levels of grain corn from varietal trial in Malaysia

Variety/location	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Aflatoxin Total (ppb)
CP 801/ Selangor	13.1	7.4	3.2	63.4	5.0
CP 888/ Selangor	11.6	6.5	3.5	65.3	5.8
CP 888/ Selangor	14.4	7.2	3.9	63.6	3.4
EKS/ Selangor	12.2	5.7	3.6	66.4	6.4
Pacific 339/ Selangor	10.8	7.4	3.7	66.8	5.2
Philippine/ Selangor	11.8	7.3	4.1	64.0	18.7
Pacific 339/ Selangor	12.1	7.4	3.7	66.8	6.4

Variety/location	Moisture (%)	Protein (%)	Oil (%)	Starch (%)	Aflatoxin Total (ppb)
EKS/ Selangor	13.8	6.7	3.3	63.8	6.4
Pioneer P4546/ Selangor	11	7.3	3.9	68.0	5.4
FAO Philippine/ Selangor	11.6	7.8	4.2	65.1	5.4
CP 801/ Selangor	10.8	7.3	4.0	67.0	8.1
Sygenta/ Selangor	12.6	8.1	3.8	63.9	16.3
Dexal79bMosanto/ Selangor	12.9	6.9	3.7	66.5	6.7
GWG 5005/ Sarawak	11.7	8.5	3.9	66.7	0.0
Pacific 339/Perak	11.8	7.8	4.0	65.6	0.0
GWG 888/Perak	11.3	6.9	3.7	67.0	0.0
Pacific 339/Kedah	11.5	9.7	4.3	66.6	4.9
Range	10.8 to 14.4	5.7 -9.7	3.2 – 4.3	63.4 – 68.0	0 – 18.7

CONCLUSION

This study provides some baseline data on the quality of grain corn from selected varieties in Malaysia. Overall, the quality of ten selected varieties of grain corn fulfilled Malaysian Standard Requirement for Animal Feeds (chemical composition and levels of BCFM) and was moderate in US Grade (No. 3 grade). All samples contained aflatoxin concentrations below the acceptable standard of 20 ppb. This study recommends a comprehensive approach to enhance the quality of grain corn in Malaysia. Key recommendations include encouraging the use of varieties that meet Malaysian and international standards, continuously monitoring aflatoxin levels, providing guidance on best practices for cultivation and post-harvest handling, investing in research and development for high-quality varieties, and conducting educational programs to raise awareness about the importance of quality standards in grain corn production. These measures collectively aim to ensure sustained compliance, improve overall quality, and contribute to the long-term success of grain corn cultivation in the country.

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ACKNOWLEDGEMENT

The authors would like to thank the Director-General, Department of Veterinary Services, Malaysia, Director of Veterinary Research Division DVS, and Director of Veterinary Public Health Laboratory for permission to publish the findings of this study. Special thanks are also conveyed to researchers of the Animal Science Research Centre MARDI Station and agricultural officers of the Department of Agriculture for their contribution to this study.