academicJournals

Vol. 12(31), pp. 4881-4890, 31 July, 2013
DOI: 10.5897/AJB12.1809
ISSN 1684-5315 ©2013 Academic Journals
http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

Inadvertent presence of genetically modified elements in maize food products in Kenyan markets

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Accepted 12 December, 2012

Kenya has a biosafety law and has tested genetically modified (GM) maize under confinement and containment, but has neither released nor commercialized any GM crop. This study assessed various maize food products from the Kenyan farms and markets for the inadvertent presence of GMOs. It assessed the possibility of 'gene-flow' to the maize farms near the Kenya Agricultural Research Institute (KARI), Kiboko where Bt maize was grown in confined field trials (CFT) during 2005 to 2006. The multistage sampling technique was used, while the polymerase chain reaction (PCR) and lateral-strip methods were used to analyze 120 food samples. Of these, 6.7% tested positive for *cry1Ab,* a globally commercialized gene, but were negative for *cry1Ba*, a non-commercialized gene. Neither *cry1Ab* nor *cry1Ba* genes were found in any of the maize certified seed samples. No 'gene-flow' was detected within the vicinity of the Kiboko CFT site. The maize imported into Kenya contained Bt genetic elements. Nevertheless, the confinement regulatory measures employed during the CFTs at Kiboko were effective. There is a need to enforce declaration of GM or non-GM and conduction of regulatory detection of food imports and for labelling of food products to enable consumers to make informed choices on what they buy and consume.

Key words: *cry1Ab*, *cry1Ba*, biosafety, GMOs, Bt maize.

INTRODUCTION

The debate on the merits and demerits of genetically modified organisms (GMOs) signals for a system that enables consumers to make informed choices about what to consume. Crop biotechnology can potentially increase agricultural yields levels by reducing yield losses from insects, diseases and drought, and enhance the nutritive value of crops. However, there is genuine concern expressed by many people about long-term negative health and environmental effects (Olembo et al., 2010).

GMOs were introduced to the world market in 1996 (James, 2004), when the USA Department of Agriculture (USDA) approved *cry1Ab* GM maize seeds and CP4-EPSPS GM soybean seeds for use as food and animal feed. GM crops, commonly referred to as biotech or transgenic crops (Olembo et al., 2010; James, 2011), are now extensively cultivated and their adoption and area under cultivation is increasing rapidly. In 2010, 148 million hectares (Mha) were planted with GMOs in 29 countries (19 developing and 10 industrial countries), by 15.4 million farmers and valued at US$11.2 billion

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Abbreviations: BGHC L2, Biosafety level II green house complex; **Bt,** *Bacillus thuringiensis*; **CFT,** confined field trial; **CIMMYT,** International Maize and Wheat Improvement Center; **CTAB,** cetyl trimethylammonium bromide; GM, genetically modified; GMO, genetically modified organism; **ILRI,** International Livestock Research Institute; **KARI,** Kenya Agriculture Research Institute.

(James, 2011), with transgenic maize occupying 46.8 Mha (31%) of the global maize area. The percentage of global biotech crops grown by developing countries has increased consistently every year over the last decade; from 14% in 1997, to 48% in 2010. The rate of growth of biotech crops between 2009 and 2010 was much higher in developing countries at 17% (10.2 Mha) compared with that of industrial countries at 5% (3.8 Mha). The lead developing countries are China, India, Brazil, Argentina and South Africa (James, 2011).

The development and dissemination of transgenic maize has made a tremendous impact on maize production, transport and marketing procedures (Scott and Pollak, 2005). Although no unfavourable reactions to Cry1Ab or CP4-EPSPS proteins have been reported, concerns have arisen regarding regulatory measures applied to GM foods. The large-scale growth of GM plants may have both positive and negative effects on the environment. These may be either direct effects on organisms that feed on, or interact with, the crops, or wider effects on food chains produced by increases or decreases in the numbers of other organisms. Thus, accurate and reliable detection of GMOs in food has become increasingly important, as the demand for the labelling of foods containing GMO increases (Carter and Gruere, 2006). Although, GMO labelling does not have any bearing on the safety of GMOs, it is used to give consumers a choice between GM and non-GM products.

In a study done in South Africa, out of 58 off-the-shelf food products sampled randomly from different retail and health outlets, 76% tested positive for GM (Viljoen et al., 2006). Of the products tested, seven maize products carried a GM related label, and GM was detected in 57% of those GM labelled maize. Two out of the three maize products with a “may be GM” label were found to contain GM. GM was also detected in 71% of all products with either a “non-GM”, “GMO free” and/or “organic” label. GM was also present in 50% of the products with a negative GM label.GM was detected in 63% of local maize products, indicating that GM production in South Africa may be higher than the estimated 24% for yellow maize and 10% for white maize.

In 1999, the Kenya Agricultural Research Institute (KARI) and the International Maize and Wheat Improvement Centre (CIMMYT) with funding from the Novartis Foundation for Sustainable Development [currently the Syngenta Foundation for Sustainable Agriculture, (SFSA)], launched the Insect Resistant Maize for Africa (IRMA) project. Its objective was to reduce the loss in yield to farmers occasioned by stem borers through the development and deployment of insect resistant maize (Mugo et al., 2005; Mugo et al., 2011a) in order to increase maize production and improve food security. Two Bt genes were used: *cry1Ab* and *cry1Ba* both of which are code for a crystal toxin, which proteolyses the digestive tract of insect larvae, leading to gut lyses, starvation and eventually death. Of the two genes, c*ry1Ab* is active against Lepidoptera while c*ry1Ba*, is active against both coleopteran and lepidop-teran larvae (Mbogori et al., 2006). Bt maize was grown in Kenya during the 200 to 2006 period under both confined field trial (CFT) sites at the KARI-Kiboko site and in a biosafety level II greenhouse complex (BGHC L2) at KARI-National Agricultural Research Laboratories (NARL), Kabete, Nairobi (Mugo et al., 2011a).

The CFT was designed for development and testing transgenic maize varieties, and risk assessment studies prior to deployment and large scale commercial release (Mugo et al., 2011b). The CFT was developed within the national biosafety framework and meets the biosafety level II international standards. The CFT’s main features and functions are to achieve genetic and material confinement. Genetic confinement is meant to prevent seeds, pollen, as well as vegetative materials from getting into the surrounding breeding and growing systems. Hence, the CFT has secure fencing to restrict access; 24 h security enhanced by locked gates, and an isolation distance of more than 800 m from other maize plots. This distance is double the recommended distance of 400 m required for breeding. The site is managed by staff trained in biosafety, while proper destruction and disposal of plant and other wastes is practiced (Mugo et al., 2011b). While all precautions of confinement were in place, concerns were raised that there was a possibility that ‘gene-flow’ from these experiments could have occurred.

During the time of this study, Kenya did not grow GM crops and no GM material was allowed into the country for consumption except for research purposes and only with approval from the National Biosafety Committee (NBC). However, Kenya has trading relations with countries that grow GM crops (especially the USA, South Africa and the Philippines) and imports food products and relief food, especially maize, from those countries. There is, thus, a possibility that GM products could have found their way into the country. This is more so, especially in recent years since the maize trade in Kenya has been liberalised. So far no study has analyzed the presence of GM in food in Kenya. This study, therefore, was aimed to assess the maize food products in the Kenyan market for the presence of genetic elements from GMOs. This was done by testing various maize food products, including grains from open air markets, relief food, maize seeds from seed companies and processed food sampled from various supermarkets in Kenya.

The specific objectives were to: (1) assess the presence of *cry1Ab, cry1Ba* genes and CP4-EPSPS (roundup ready) proteins in maize food products consumed in Kenya; (2) assess the presence of *cry1Ab* and *cry1Ba* genes as indicators of gene flow from the KARI Kiboko CFT site to the surrounding farms; (3) determine if selected maize food products in supermarkets had Cry1Ab proteins; and (4) Identify whether or not maize food products were labelled as GM

or non-GM.

MATERIALS AND METHODS

Sample collection

A multi-stage sampling technique was adopted in this study (Castillo, 2009). In the first stage, provinces in Kenya were selected. North Eastern province, which is neither a major maize producer nor consumer, was purposely eliminated from the sampling frame. Of the remaining seven provinces, four provinces were randomly selected: Nairobi, Coast, Eastern and Western. In the second stage, 10 towns were selected randomly from urban centres in the selected provinces: Nairobi, Mombasa, Kitui, Machakos, Mwingi, Makueni, Kakamega, Mumias, Busia, and Bungoma. Kiboko town where the CFT site is situated was later added, resulting in a total of 11 towns. The third stage was categorization of the towns selected relative to their importance in the maize industry. The criteria used were either these towns were: main port and entry point into the country; main distributor and consumer; and main consumer of relief food or major producer. Hence based on those criteria, the towns were categorized as follows: 1) Mombasa is the main port and entry point into the country of most of the imported food products, including maize; 2) Nairobi is the main city which receives, processes and distributes imported maize grains, and is a major consumer; 3) Kitui, Machakos, Mwingi, and Makueni are the main towns in areas frequently hit by drought and which receive and consume a large share of the relief food grains; 4) Kakamega, Mumias and Bungoma are the main towns located in the areas that are both major maize seed growers and important grain maize producers; and 5) Busia, a town on the Kenya-Uganda border, is also an entry point for maize seeds and grains from Uganda, and is located in a major maize-producing area. A significant level of trade in maize takes place here.

In the fourth stage, open air markets, supermarkets and seed companies were selected. Three markets were randomly sampled from Mombasa and seven from Nairobi. However, since the other towns have only one open air market each, those markets were purposively selected. Three supermarkets and four seed companies were also randomly selected from Nairobi. A total of 21 markets were selected from which maize grains and processed maize products were obtained.

The final stage was a random selection of the different samples of maize foodstuffs from these 21 units, including 91 maize grains obtained from various open air markets and retail shops located in various towns in Kenya (Table 1). Other samples were five maize seeds obtained from different seed companies operating in Kenya, four samples of maize flour, five corn flakes and three pieces of popcorns obtained from supermarkets located in Nairobi. Finally, 12 maize grains samples were collected from farms in Kiboko within a radius of about 1 km from the CFT site where the Bt maize had been grown. A total of 120 samples were, thus, obtained for the study. The samples were analysed for the presence of the *cry1Ab* the extensively commercialized gene and fo*r cry1Ba* the non commercialized genes with the polymerase chain reaction (PCR). The PCR analysis was carried on 115 maize grain and seed samples. However, the lateral flow strips (Dipsticks) method was done on all the 120 samples where Cry1Ab and Round up ready protein was tested as described below.

Extraction of DNA from maize samples for PCR analysis

For DNA extraction, 30 grains and certified seeds were ground into fine flour with mortar and pestle, with care taken to prevent contamination of the resultant flour. DNA was extracted from each of the 120 maize food product samples using the 3% cetyl trimethylammonium bromide (CTAB) protocol described by Rania et al. (2009). 5 µl aliquot of extracted DNA was loaded in 1% (w/v) agarose gel. The gel was stained with ethidium bromide and electrophoresed at 40mA for 1 h to assess the DNA yield and quality.

Molecular detection of *cry1Ab* and *cry1Ba* genes by PCR

The molecular detection of *cry1Ab* and *cry1Ba* genes by PCR was in a final volume of 25 µl containing 1.5 mM $MgCl_2$, 0.2 mM dNTPs, 0.25 µM primers, 1.25 U Taq polymerase, 1 x PCR buffer and 40 ng DNA template. PCR amplifications were carried out using a GeneAmp PCR system 9700, Applied Biosystems. All reagents were obtained from Invitrogen Kenya, except for primers that were acquired from Biosynthesis Inc, USA through the International Livestock Research Institute (ILRI), Nairobi. The primers used and their sequences were those used by Mbogori et al. (2006): *cry1Ab*: 5'-ACCATCAACAGCCGCTACAACGACC-3'; 5'-TGGGGAACAGGCTCACGATGTCCAG-3'; *cry1Ba:* 5'-CCATGGTTACCTCCAACCGT-3'; 5'-GGATGATCTCGATCTTGTCGA-3'.

The conditions for amplifications were: initial denaturation of DNA at 94°C for 2 min, 35 cycles of 1 min at 94°C, 1 min at 68°C, 1 min at 72°C and a final extension at 72°C for 10 min (Mbogori et al., 2006) with the exception of *cry1Ba* where the annealing temperature was a bit low at 54°C. 5 µl of the amplified products were electrophoresed in 2% agarose gel stained with Ethidium Bromide (EtBr) for 1 h at 40 mA. The positive and negative controls for the PCR reactions were obtained from CIMMYT/KARI (Mugo et al., 2011a).

Lateral flow strip or dipstick for detection of Cry1Ab and CP4 (roundup ready) proteins

All protein strip test analyses were performed following the manufacturer's procedures *incasu* Envirologix, Neogene or Strategic Diagnostics (Van den Bulcke et al., 2005). The results were read and recorded accordingly. The Bt maize Event 223::*cry1Ab* was used as the positive control for Cry1Ab protein while non Bt maize seeds were used as the negative control for this reaction (Mugo et al., 2011a). There was no positive control for CP4 (roundup ready) protein because it has not been introduced in the country. The appearance of one line at the control line indicated negative results, while the appearance of two lines both at the control and test line indicated positive results.

RESULTS

DNA was successfully extracted from 115 samples out of the 120 samples randomly collected from various markets in Kenya using the 3% CTAB protocol. However, extraction from the five corn flakes (Kellogg's, Nestle, Magic, Bokomo and Temmy) was not successful.

Assessment of *cry1Ab* genes from maize samples collected from open-air markets in different towns in Kenya

The results of the PCR analysis show that only five

Table 1. Sources of Maize samples analysed for the presence of GM genes in Kenya.

Province	Number	Sample source (market)	Sample Identity (maize)	Number of sample
Eastern	1	Makueni	Makueni 1-5	5
	2	Mwingi	Relief food (maize)	1
	3	Mwingi	Relief yellow maize	1
	4	Mwingi	Mwingi 1-5	5
	5	Kitui	Kitui 1-8	8
	6	Machakos	Machakos 1-5	5
	7	KARI Kiboko	CML202	1
	8	KARI Kiboko	CML204	1
	9	Kiboko farmers	Farmers 1-10	10
Nairobi province	10	Kangemi	Kangemi 1-5	5
	11	Wakulima	Wakulima 1-5	5
	12	Ngong	Ngong 1-5	5
	13	Kitengela	Kitengela 1-5	5
	14	Karen	Karen 1-5	5
	15	Toi	Toi 1-5	5
	16	Mulolongo	Mulolongo 1-4	4
	17	Monsanto Seed Co.	DK 8031	1
	18	Kenya Seed Co.	H513	1
	19	Kenya Seed Co.	DH04	1
	20	Seedco Seed Co.	D41(Duma)	1
	21	Pannar Seed Co.	PAN 67	1
Coast	22	Kongowea	Mombasa 1-3, 6,7	5
	23	Kilindini	Mombasa 4 & 5	2
	24	Marikiti	Mombasa 8-12	5
Western	25	Busia	Busia 1-5	5
	26	Bungoma	Bungoma 1-5	5
	27	Kakamega	Kakamega 1-5	5
	28	Mumias	Mumias 1-5	5
	Total			108

CML, Control maize line; Co., company; D, Duma; K, Kenya; H, hybrid; PAN, Pannar. Source: Researcher's field data, December 2009 to March 2010.

(5.5%) of the 91 samples collected from the open air markets contained *cry1Ab* genes (Figure 1). Of the five positive samples, four (4.4%) came from Mombasa and one (1.1%) came from Nairobi. The rest of the maize samples tested negative for the *cry1Ab* gene. There was no amplification for non Bt control maize CML216 as shown in Figure 1.

All the samples were also subjected to the lateral flow method to test for Cry1Ab proteins. Then, five (5.5%) samples that had tested positive by PCR also tested positive for the protein (Figure 2). Thus, the five maize samples that were positive for *cry1Ab* gene by PCR method, were also positive for Cry1Ab proteins. The rest of the samples were negative for Bt protein. Again, the same five (5.5%) maize grain samples also tested positive for the CP4 (roundup ready) protein (Figure 3).

Detection of *cry1Ba* genes in maize samples collected in open air markets in different towns in Kenya

The samples from various randomly-selected open air markets in Kenya were tested for *cry1Ba* genes. The positive controls amplified PCR products of 70 bp (Figure 4). On the other hand, no band was observed for the negative control and for all the samples collected from the various markets in Kenya. This shows that none of the samples collected from the various markets in Kenya contained *cry1Ba* gene.

Detection of cry1Ab gene for gene flow from KARI Kiboko CFT site to the non targeted maize farms.

The 12 samples collected from KARI Kiboko and from

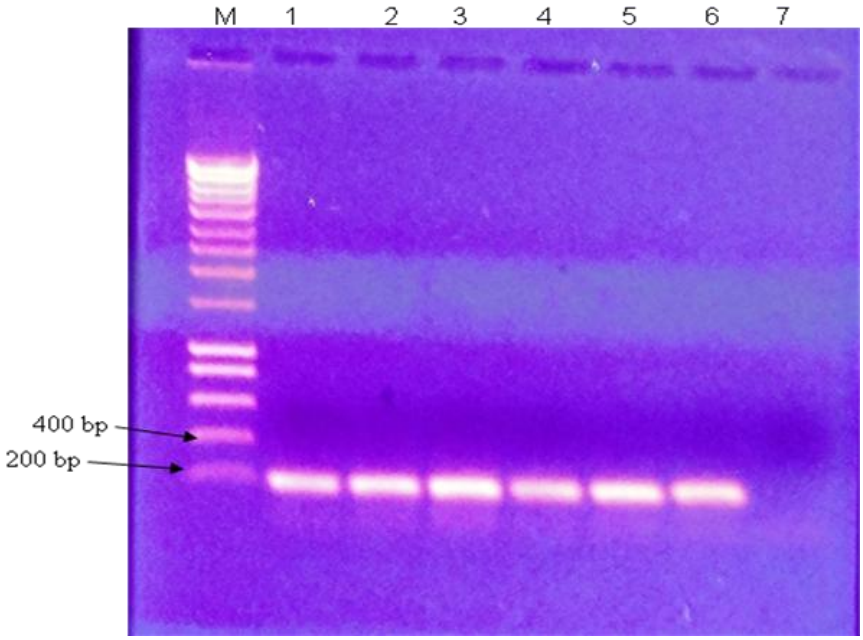

Figure 1. PCR results from five positive maize samples, a positive and negative control lanes amplified with *cry1Ab* primer. M, Molecular weight ladder (Hyper ladder 1 bioline-ranging from 200 base pair (bp) to show the band of interest; lane 1, Mombasa 1; lane 2, Mombasa 2; lane 3, *Bt* event::*cry1Ab* (positive control); lane 4, Mombasa 3; lane 5, Mombasa 4; lane 6, Kangemi 1; lane 7, negative control (CML 216); the samples were amplified with *cry1Ab* primers.

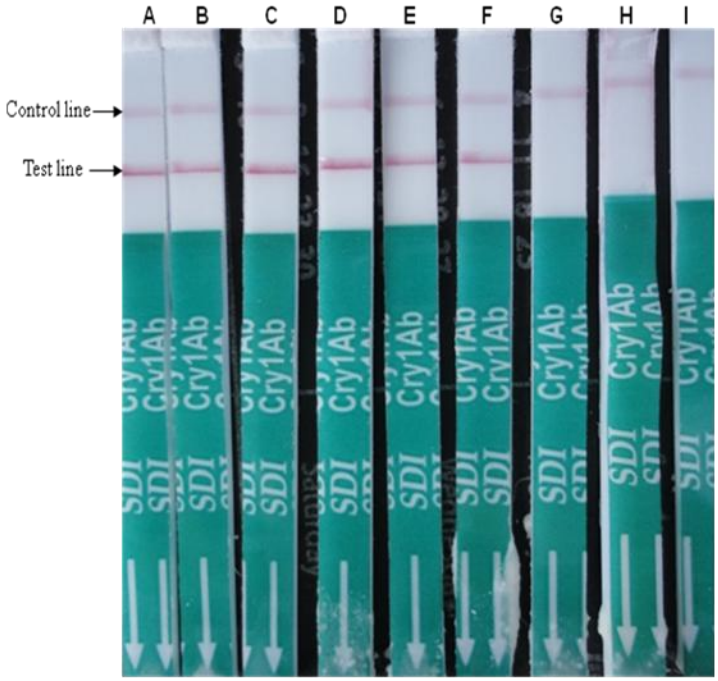

Figure 2. Cry1Ab protein results for some of the maize samples collected and two *cry1Ba* Bt event maize. Strip A, Mombasa 1; strip B, Mombasa 2; strip C, Mombasa 3; strip D, Bt maize event 223::*cry1Ab*; strip E, Mombasa 4; strip F= Kangemi 1; strip G= CML 216; strip H= Bt maize Event 6::*cry1Ba*; Strip I= Bt Event 10::*cry1Ba.*

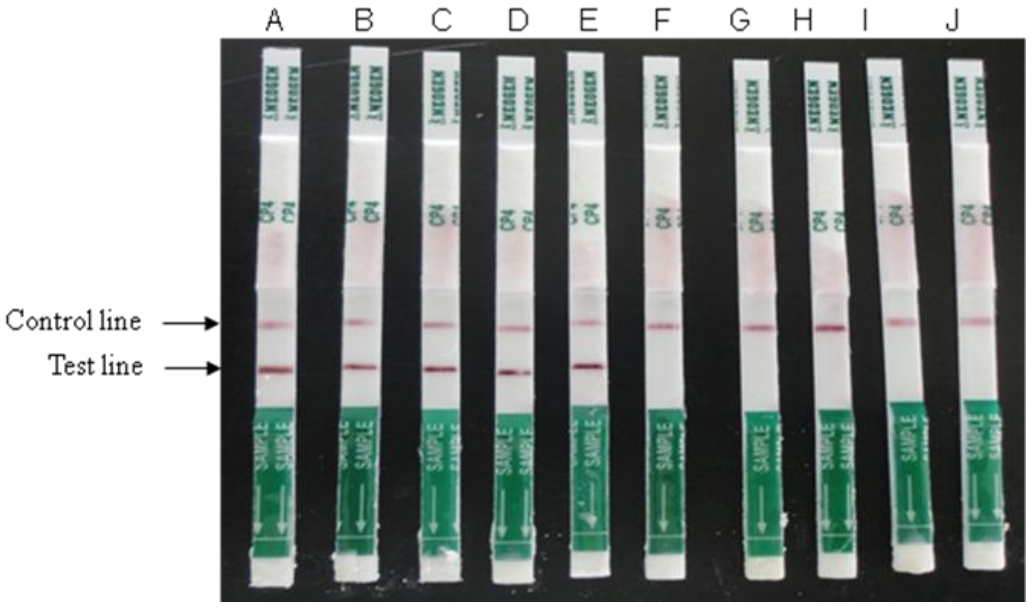

Figure 3. CP4-EPSPS lateral strip results for maize grains and seeds. A, Mombasa 1; B, Mombasa 2; C, Mombasa 3; D, Mombasa 4, E, Kangemi 1; F, Bt Event 223::cry1Ab (positive control for Cry 1Ab); G, Bt Event 6::cry1Ba; H, Bt Event 10::cry1Ba; I, CML 216 (negative control); J, CML202 (negative control).

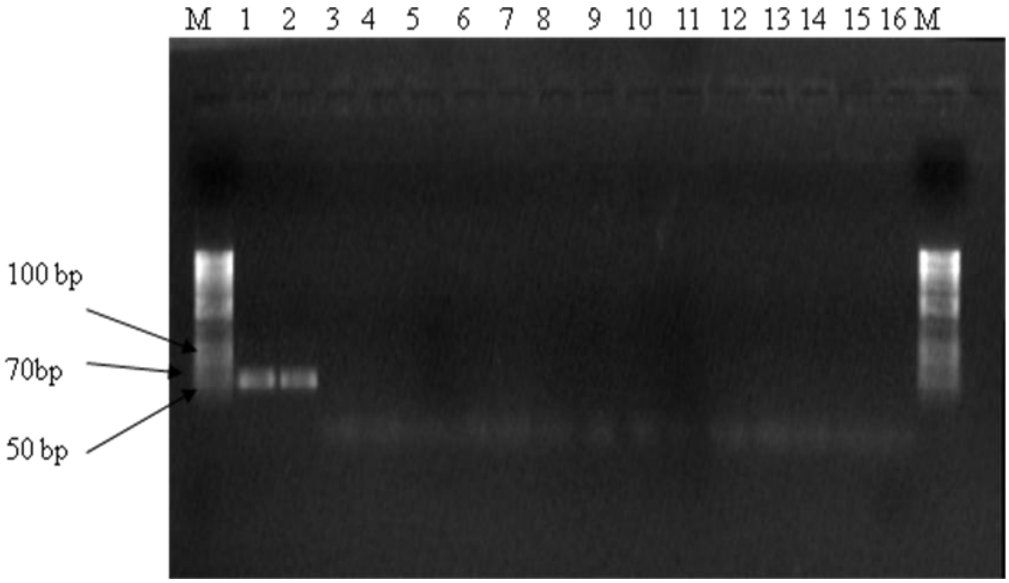

Figure 4. Amplification of DNA from maize grains with Cry1Ba primer to detect *cry1Ba* gene. M, Low molecular weight ladder 50 bp from fermenters; lanes 1 to 2, Bt positive control maize grains (Bt maize event 6::*cry1Ba* and Bt maize event 10::*cry1Ba*); lane 3, Bt maize event 223::*cry1Ab*; lanes 4 to 9, *cry1Ab* samples amplified with *cry1Ba* primers; lanes 10 to 11, non Bt control maize samples; lanes 12 to 16, negative results collected for maize samples amplified with cry1Ba primers.

Kiboko farmers, as well as the negative control, did not amplify the expected band of *cry1Ab* gene (Figure 5). However, the positive control amplified the expected band of 200 bp. No gene flow occurred from the CFT to other maize in its vicinity.

The samples from Kiboko were also tested for the

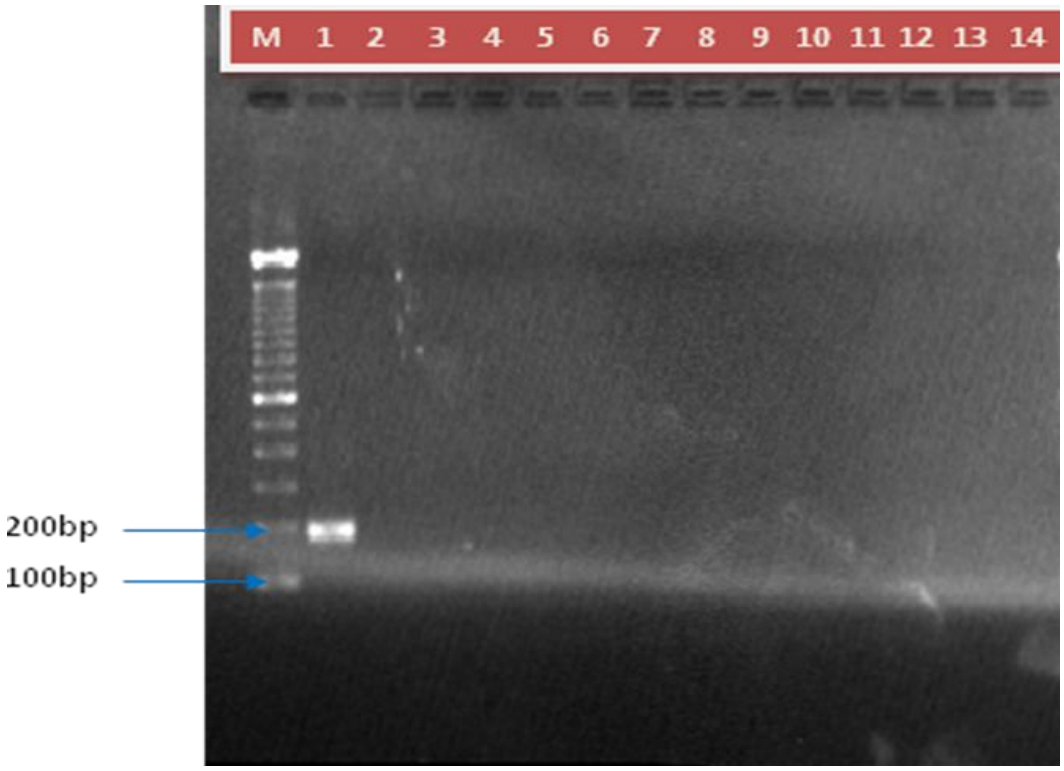

Figure 5. Detection of *cry1Ab* gene for gene flow to non target maize fields. M, Molecular weight ladder 100 bp from Invitrogen; lane 1, Bt maize Event 223::*cry1Ab*; lane 2, CML202; lane 3, CML204 (samples from KARI-Kiboko); lane 4, CML216 (negative control); lanes 5 to14, maize samples from farmers in Kiboko.

presence of Cry1Ab protein by using Cry1Ab strips to confirm the results obtained by PCR analysis. Similarly, Cry1Ab protein was not detected in any of the samples as with the PCR technique and neither was CP4-EPSPS protein detected.

Detection of transgenes in the certified hybrid seeds

All certified hybrid seeds tested negative for *cry1Ab* commercialized gene, *cry1Ba* the non-commercialized gene, and Cry1Ab and CP4 (roundup ready) proteins.

Detection of *Cry1Ab* proteins in processed food products

All samples used were not labelled for the presence or absence of any GMO. The 12 samples collected from supermarkets were tested for Cry1Ab proteins with the use of Cry1Ab protein strips and, three (25%) cornflake samples were positive for Cry1Ab protein (Figure 6). The three packets that tested positive were imported from UK, Philippines and the USA. No Cry1Ab protein was detected in the rest of the samples.

Geographical spread of the positive samples

The distribution of positive maize samples containing *cry1Ab* gene came from two geographical areas, Coast and Nairobi provinces. The samples from Coast had a higher percentage of 3.33% while that for Nairobi province was 0.83%. It was further noted that out of the 12 processed samples collected from supermarkets in Nairobi, three (2.5%) cornflakes contained Cry1Ab protein and were manufactured from those countries which grow GM crops (UK, USA and Philippines).

DISCUSSION

DNA was recovered for PCR amplifications from 115 of the maize samples. These confirmed that the CTAB DNA extraction method used was adequate for the extraction of amplifiable maize DNA from the samples and this is in agreement with the results of Yoke-Kqueen et al. (2011). However, DNA extraction from the five corn flakes (Kellogg's, Nestle, Magic, Bokomo and Temmy) was not successful. This findings concur with those of Margarit et al. (2006) who found out that it was not possible to obtain good quality DNA for PCR from highly processed foods,

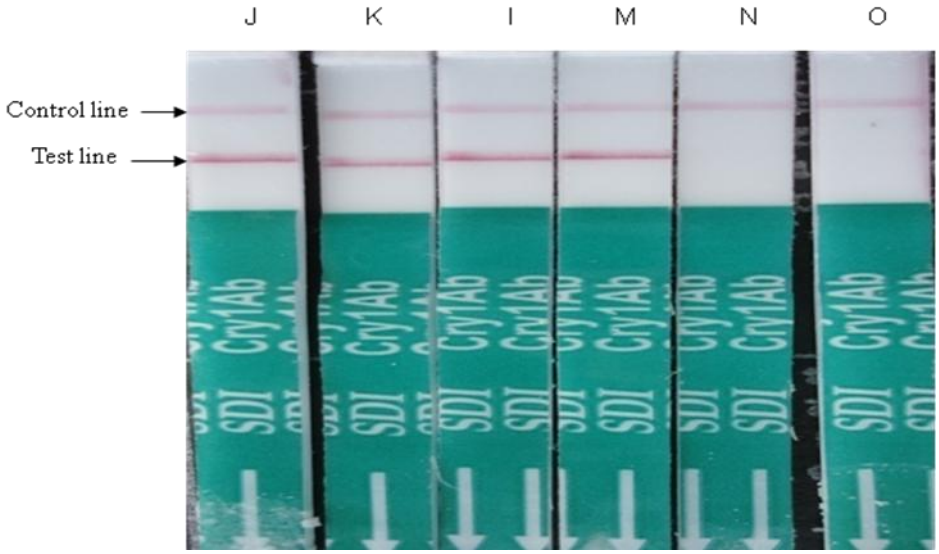

Figure 6. Lateral flow strip results for cornflakes tested for Cry1Ab protein. Strip J, Bt Event 223::*cry1A*; strip K, corn 2; strip I, corn 3; strip M, corn 4; strip N, CML 216; strip O, corn 1.

such as corn flakes, corn puffs and corn syrup. These results suggest that high temperatures or other factors involved in the processing of the cornflakes degraded the *cry1Ab* DNA.

PCR is very efficient in detecting genetically modified genes in Bt maize seed and grains because it was able to amplify the *cry1Ab* gene in five of the maize samples. The findings are in agreement with a study done by Randhawa and Firke (2006). The results provided evidence for the presence of *cry1Ab* gene in 5.5% of maize grains consumed in Kenya. These findings are in agreement with other studies done in other countries where the *cry1Ab* gene was detected in maize food products using PCR. An example is a study which was done in Argentina by Margarit et al. (2006). Through PCR analyses, a fragment of 204 bp was amplified from commercial maize (Margarit et al. 2006). The transgenes were detected in two precooked and one non-cooked polentas and two cracked maize. The findings further concur with a study done in South Africa by Viljoen et al. (2006) where they detected GM maize in samples randomly collected in different retail outlets. There are, therefore, GMOs in the Kenyan maize market.

The maize samples were also analyzed for Cry1Ab protein using the lateral flow strip method. The results show that the same set of samples that were positive for the *cry1Ab* gene were also positive for Cry1Ab proteins, thus the two methods were in agreement. Lateral flow strip tests confirmed that it can be used as a simple, cheaper and more rapid tool (Van Duijn et al., 2002) than the PCR-based GMO detection method which is costly in terms of equipment and operation, and highly-trained personnel are required. In addition, sample analysis requires longer time of at least one day (Asfaw and Tewodros, 2008).

The same set of maize samples that tested positive for the *cry1Ab* gene and Cry1Ab protein were also positive for the CP4-EPSPS protein. The maize samples were likely double-stacked with pest-resistant (Cry1Ab) and herbicide-tolerant (CP4-EPSPS) proteins. This concurs with the findings of James (2011) who found double-stacked maize with pest-resistant and herbicide- tolerant traits being the fastest growing component in 2010. According to the regulatory practices within the EU, stacked events are considered new GMOs: prior to marketing they need regulatory approval, including an assessment of their safety, as is similar to single events (De Schrijver et al., 2007).

All samples collected from KARI-Kiboko and Kiboko farmers tested negative for both genes and protein, indicating that there was no gene flow detected from the CFTs to other maize in its vicinity. This shows that the biosafety regulations and precautions that were in place were adhered to and were effective in ensuring genetic confinement of the Bt maize. The measures included isolation by distance, harvesting before maturity, disposal in pits, and restricted access to the site (Mugo et al., 2011b). Since maize is wind pollinated, with fertilization occurring at up to 200 m (Ma et al., 2004), the doubling of the distance between the experimental site and the neighbouring maize farm, from 400 m (required for breeder seed production) to 800 m, might have reduced the chances of gene flow from any pollen (Mugo et al., 2011b). This concurs with other studies on pollen gene flow from Bt maize to non Bt maize.

Given that pollen concentrations and thus cross-

Table 2. GM approval and labelling regulations in major trading countries.

Country	Mandatory or Voluntary safety assessment M/V	Political approved required	Mandatory or Voluntary labelling M/V	Labelling based Process (p) or end product (E)	Labelling tolerance level
Australia/ New Zealand	M	Y	M	E	1%
Brazil	M	Y	M	P	1%
Canada	M	N	V	E	5%
China	M	Y	M	E	0%
EU	M	Y	M	P	0.9%
Japan	M	Y	M/V	E	5%
Korea	M	Y	M	E	3%
Russia	M	Y	M	P	1%
United States	V	N	V	E	5%

M, Mandatory; V, voluntary; E, end product; P, process. Source, Carter and Gruère (2006).

fertilization levels rapidly decrease with the increased distance from the pollen source, spatially isolating GM maize fields from non-GM maize fields is an effective on-farm strategy to reduce the extent of cross-fertilization. As maize pollen is fairly heavy, the vast majority is deposited within a maximum of 18 to 20 m distance from the emission source, minimizing the chances of cross-fertilization occurring beyond this distance (Devos et al., 2005).

In defining science-based isolation distances between GM and non-GM maize field's, cross-fertilization rates have been studied, both in experimental and commercial fields. Gene flow was followed based on Bt maize sequence information (Sorina et al., 2010; Chilcutt and Tabashnik, 2004; Joaquima et al., 2006). The results obtained from experimental fields in Romania's three refugee areas (Chiciu, Chirnogi and Gătaia) show that the maximum distance where the GM content was below 0.9% for all of the four geographic directions was 21 m in 2007. However, further experiments done in the same sites in 2008 found the maximum distances for the same threshold of below 0.9% to be 25 m (Sorina et al., 2010).

Of the processed maize food products sampled from various supermarkets in Kenya, only three cornflakes (cornflakes 2, 3, and 4) were positive for Cry1Ab protein. The cornflakes were made from GM maize and there were some traces of protein left during processing. This is in agreement with a study done in Argentina by Margarit et al. (2006). In this study, Cry1Ab protein was detected in low processed foods such as chicken feed and pre-cooked polenta. In cornflake 1, cornflake 5 and in the rest of the samples no Cry1Ab protein was detected. This was probably because the corn used was not GM, or high temperatures and other factors involved in the processing degraded the Cry1Ab protein (Margarit et al., 2006). From the results, some of the processed maize products sold in the supermarkets contained Cry1Ab proteins.

However, the quantity of *cry1Ab* genes, Cry1Ab protein and CP4 (roundup ready) protein in the positive samples in this study was not ascertained. Thus, it is likely that the transgenes present in the samples, which tested positive for GMOs, could be above or below the accepted thresholds of 1 to 5% (Table 2).

Conclusions

This study did not find any 'gene-flow' from the CFT to the farmers' farms around KARI-Kiboko. This implies that the isolation distances and measures required by Kenya Plant Health Inspectorate Services (KEPHIS) were sufficient to confine the transgenes. Nonetheless, there were genetically modified maize food products in the Kenyan market carrying the maize Bt gene *cry1Ab*, and the Cry1Ab and CP4 (roundup ready) proteins because 6.7% of the total number of samples (120) tested positive. The greater presence of GMOs in the samples from Mombasa shows that the major source is the import of maize grains through the Kenyan port.

The positive GM results require further analysis to quantify the transgenes present and this can be achieved by performing real-time PCR. This was not done because applying this method is quite expensive compared to conventional PCR methods. As well, KARI-NARL, where the analysis of this study was done, does not have real-time PCR equipment.

The lateral strip method can be used for quick identification of GM material in maize food products. It enabled the detection of Cry1Ab protein and herbicide resistant CP4 (roundup ready) proteins in the five maize samples and the three cornflakes that tested positive. The results obtained using this method were the same as those under the PCR amplification method that detected the *cry1Ab* gene in the same five maize samples. Thus, the lateral strip method can be a reliable and rapid method

for detection of GM materials in various food products in Kenya to enable consumers to make informed choices.

ACKNOWLEDGEMENTS

We thank the Director KARI for allowing the experiments to be done in the KARI Biosafety Laboratory/Green House Level 2 and the Molecular Laboratory based at KARI-NARL. The Late Dr. Joel Mutisya, Officer in charge of the Biotech Centre is greatly acknowledged for his guidance and training in biosafety. We thank the Syngenta Foundation for Sustainable Agriculture for the support towards the preparation and publication of this paper.

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