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Ascertaining the Presence of Genetic Modification in Seeds, Processed Food, and Feed Products in Namibia

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ABSTRACT

The study aimed to assess whether the seeds in Namibia were derived from genetic modifications and whether grains, processed foods, and feed products contain genetically modified (GM) content. A multistage probability random sampling strategy was used to collect samples from eight regions: Khomas, Zambezi, Ohangwena, Omusati, Otjozondjupa, Kavango East, Kavango West, and Oshikoto. A total of 20 maize food samples were randomly sampled from Khomas; 2021 (5), Otjozondjupa; 2020 (2), Omusati; 2021 (1), Oshikoto; 2015 (3), Ohangwena; 2015 (2), Zambezi; 2020 (2), Kavango East; 2020 (1), and 2015 (4). A total of five (5) wheat food samples were obtained from Kavango East in 2015, and one (1) mixture of canola and soy was sampled from Otjozondjupa. In addition, one feed sample was taken from Otjozondjupa. DNA was isolated using the GeneSpin DNA extraction kit. The DNA concentration was confirmed by spectrophotometry using a NanoDrop (ThermoFisher Scientific, Waltham, MA, USAtific, USA). The purity of the DNA was confirmed through visualization using agarose TBE gel electrophoresis. Screening for the adventitious presence of GM content, the Eurofins GMO Screen RT IPC (NR) 35S/NOS/ABII kit was used. Most (41.5%) of the maize samples screened for the presence of GMO content showed positive results for food samples. In 2015, all three foods sampled in the Ohangwena region tested positive, while in the Oshikoto region, two samples also contained GM content. All wheat samples tested negative for GMOs during the two years. The overall study shows the prevalence of GMOs in Namibia.

Keywords: DNA$_1$, 35S$_2$, NOS$_3$ CAMV$_4$, GMOs$_5$, GM Products$_6$

INTRODUCTION

Genetically Modified Organisms (GMOs), in this context, are plants that have been genetically altered to include foreign genes. Numerous plant species have recently undergone genetic modification to acquire traits such as the introduction of genetic traits that enable crops to be insect-resistant (Bouwer, 2020; Farinós et al., 2018). Other genetic modifications include effectively withstanding drought, heat, and saline conditions by crops (Noori et al., 2021). Furthermore, according to Musa Maryam (2017), genetic engineering has improved the appearance, texture, flavour, shelf life, and nutritional value of food. However, the three most common traits found in Genetically Modified (GM) crops are that they are resistant to insect damage and plant viruses while also being tolerant to herbicides. A tomato cultivar that was not susceptible to decay called Flavr Savr was introduced to commercial cultivation in the USA in 1994 and was the first GM plant (Redenbaugh, 2014). However, there is still a lot of controversy about the usage of GM in food and feed products. Although there are contradicting views on the potential dangers of genetically modified (GM) food and feed are put through extensive safety assessment (Bawa & Anilakumar, 2013). GM crops have been linked to

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negative environmental effects, notably the loss of biodiversity (Schütte et al., 2017). Pesticide and herbicide usage, among other things, has also been reported to have resulted in the extinction of many plant and animal species as well as the loss of weed species that served as havens for several pests and insects (Schütte et al., 2017).

Research has indicated that soya and maize fields have proved that milkweed, *Asclepias syriaca*, is a habitat for Monarch Butterflies (Pleasants & Oberhauser, 2013; Schütte et al., 2017). Bees from the *Apis* family, in addition to the Monarch Butterfly, are well-known for being important beneficial insects in agricultural settings (James & Pitts-Singer, 2008). It has been estimated that about 35% of agricultural crops have been pollinated by animals, with an estimated economic value of about USD 29 billion recorded in 2010 (O'Brien & Arathi, 2018). However, the value of pollinators goes beyond pollination as they are also key contributors to plant health. Bumble bees, honeybees, wild bees, and syrphid flies maintain the ecosystem by preserving plant community structures, and genetic diversity, and safeguarding reproductive (O'Brien & Arathi, 2018). In terms of GM feeds, a study conducted by (Yu, 2021) on pregnant goats with genetically modified soybeans consequently affected the growth of the goat foetus by finding out that the weight of the internal organs of the goat offspring fed with GM hay was lighter as compared to those of springs fed with conventional oat hay. Therefore, the genetic materials of GM crops are frequently compared to their conventional counterparts to analyse intended and unintended outcomes as well as their potential influence on the nutritional quality, environment, humans, and animals (Karalis et al., 2020).

GM plants have formed an essential part of agricultural production, and an increasing number of GM plant species are now easily accessible on the market (Jacobsen et al., 2013); (Lucht, 2015). Interestingly, just 1.7 million hectares of GM crops were farmed worldwide in 1996, but by 2015, 179.7 million hectares, or over 10% of the world's arable land, have been planted with GM crops (James & Pitts-Singer, 2008). This is an indication of the enormous growth in the total area of cultivation of GM crops. The Namibian Newspaper on 8 March 2022 indicated that some 96% of the maize imported came from South Africa, and 4% from Zambia. Given the status of the global food chain and the substantial amount of Namibia's food supply that is imported, it was always feasible that a sizeable portion of the food and feed products sold in Namibia may contain GM content. This was asserted by the Namibia Consumer Trust (NCT) and Ministry of Agriculture, Water and Forestry who confirmed that the first GM traces in maize meal were found on shelves in stores in Namibia in October 2012, and the second traces were found in October 2013 (Namibian Economist Newspaper, 2013). A study conducted by Kavishe et al. (2022) further revealed the presence of GM content in the food chain in supermarkets in Namibia. The prevalence of GM content in food and feed has consequently, led some nations to decide that it is appropriate to pursue the identification and monitoring of GM content in products (Al-Salameen et al., 2012). Identification of GM content in product will further consumer choice to decide whether they will love to purchase GM products.

According to the Biosafety Act 7 of 2006 (Act No. 7, 2006), no one is allowed to illegally deal in GM products without a permit for such activity. GM food and feed that are placed on the market should be approved by the Minister responsible for Science and Technology and must be declared safe for human and animal consumption as well as the environment. The permit conditions for placing on the market of GM products include the labelling of such products. However, this also requires monitoring for compliance by regulatory bodies to ensure that any product that may contain GMs and have permits needs to conform with the labelling requirements. To monitor for illegal dealing of GM regulatory bodies are allowed to randomly sample products and ascertain the presence of GM contents. Polymerase Chain Reaction (PCR) is used for qualitative and quantitative analysis to ascertain the presence of GMs in products due to their specificity, sensitivity, and robustness. There has been no testing done to objectively determine the presence of GMs in processed food and feed products marketed in different regions, therefore it is uncertain how prevalent they are throughout Namibia.

A study conducted by Kavishe et al. (2022) has confirmed the presence of GM content in Soya and chicken feed, in the Namibian supermarkets. Kavishe' s study, however, had a weakness since it only examined 9 purposefully sampled maize samples (6 food and 3 chicken feed samples), neglected to consider the regional market for these products, and omitted items like wheat and canola food, feed, and seeds. This research filled this gap. Randhawa et al. (2016) argue that the existence of GMs in processed food items is subject to transparency regulations or constraints that have been implemented in several nations worldwide. This may be accomplished by putting in place the capabilities to assert the presence of GMs in processed food and feed products (Marzia Ingrassia et al., 2017). Furthermore, it's critical to safeguard the consumer's access to information so they may decide for themselves whether to accept or reject processed GM food products. Thus, the objective of this investigation was to ascertain GM content in seeds, processed food, and feed products, in Namibia. Analytical techniques that can identify the inserted foreign DNA in a particular crop are necessary to monitor and verify the presence and quantity of GM-derived substances in processed food items (Rabiei et al., 2013). The findings of screening samples of wheat, maize, soy, food, and feed products obtained from various regions of Namibia for the detection of GMs are presented in this study.

MATERIALS AND METHODS

Sampling Procedures and Sample Size

Geographical area

The multistage sampling technique was a method used because of the geographical diversity of the targeted sampling population for this study, which is a sampling from different regions of Namibia (Sedgwick, 2015). Multistage sampling step by step process involves moving from a wider sampling to a narrower process (Palinkas et al., 2015). There are different levels of multistage sampling, which are: Multistage I, Multistage II, and Multistage III. The Multistage II sampling method involves more than three-stage sampling (Palinkas et al., 2015). The first stage in multistage sampling involved identifying regions to be sampled for this study. Eight regions were sampled, namely Khomas, Zambezi, Ohangwena, Omusati, Otjozondjupa, Kavango East, Kavango West, and Oshikoto region. Random sampling was further used to sample from these regions (Figure 2).

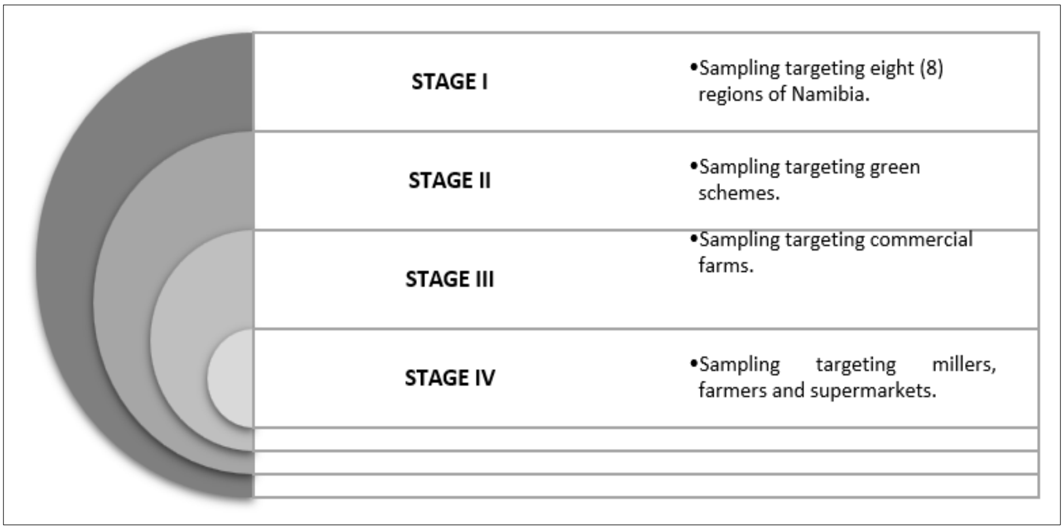

Figure 1: Stages in Multistage sampling method used

The Khomas region was selected as this is where Windhoek, the capital city of Namibia, is situated and most of the products imported are likely to end up in retailer shops and distribution outlets. Omusati, Zambezi, Kavango East, Ohangwena and Kavango West region regions contain the entry borders, and food products are likely to end up on shelves of supermarkets, open markets, and retail outlets within these regions.

The second stage of sampling is the focus on the main government green scheme farms, which has a total irrigable area of 5,318 hectares (AGRIBUSDEV, 2017). Therefore, Zambezi, Omusati, Kavango East, and Kavango West were selected because they contain main green schemes that plant mostly large hectares of maize year in and year out, seeds and grains were further sampled randomly from green schemes facilities. These regions were also selected because this is where plant bleeding research is taking place, some seeds were randomly sampled from the research stations.

The third multistage sampling focused on the central triangle area where commercial activities for maize are taking place. Therefore, random sampling of seed samples took place in commercial farms in both Oshikoto and Otjozondjupa (Tsumeb, Grootfontein, and Otavi farms). The fourth stage of sampling targeted millers, farmers, and supermarkets (grains, processed and semi-processed). Maize food and feed products were randomly sampled from different supermarkets, retailers, and open markets.

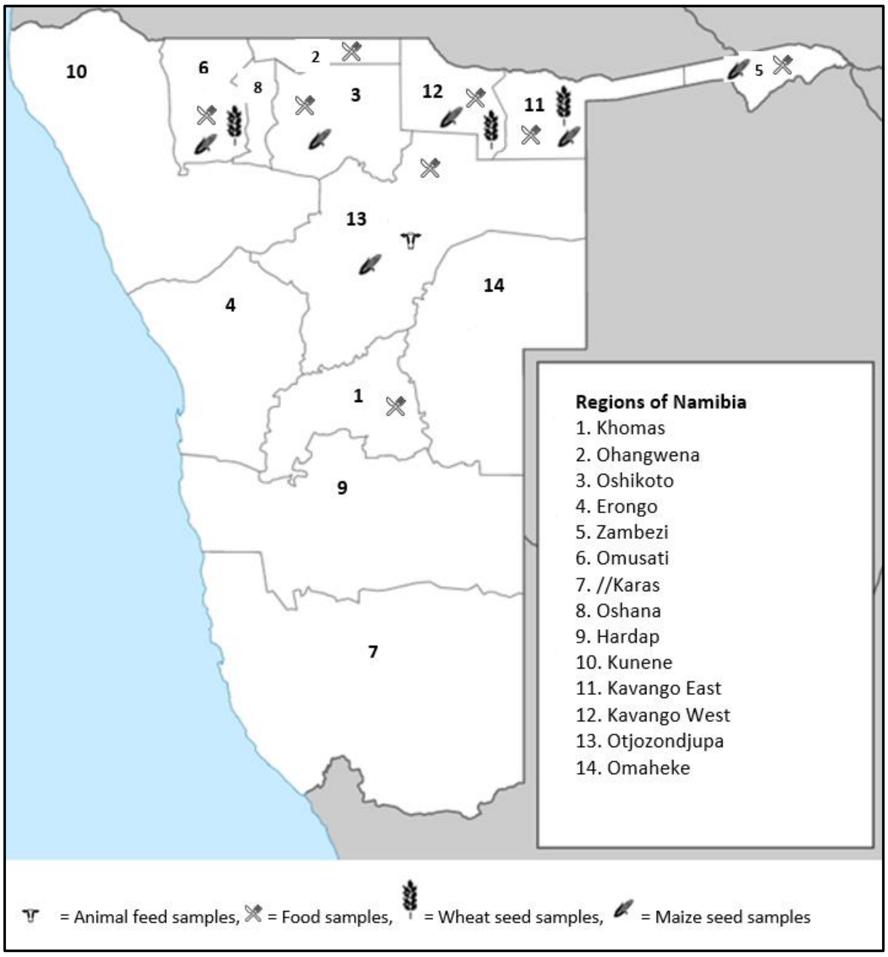

Figure 2: Geographical location of samples

Feed and Food Sample Brands

Samples obtained from the markets were of different brands (Table 1), ranging from maize meal (5 brands), corn-soya (1 one brand), instant maize porridge (1 brand), cornflakes

(1 brand), cereal maize meal (1 brand), and baby cereal (1 brand). This was done to ensure that different products supplied by different processors were included in the sampling.

Table 1: Food and feed sample brands

Food product	Sample no/Code	Crop
Brand 1- Maize meal	05/MF01/20	Maize
Brand 2-Maize meal	11/MF02/20	Maize
Brand 3-Maize meal	13/MF03/20	Maize
Brand 4-Corn-Soya meal	13/CS-F04/20	Maize-Soya
Brand 5-Maize meal	13/MF04/20	Maize
Brand 6 -Maize meal	01/MF04/21	Maize
Brand 6 -Instant maize porridge	01/MF06/21	Maize
Brand 7- Cornflakes	01/MF07/21	Maize
Brand 7- Cereal maize meal	01/MF09/21	Wheat
Brand -8 Baby cereal	01/WF01/21	Wheat
Feed product	**Sample no/Code**	**Crop**
Yellow maize seed/grains	13/MFE01/20	Maize

Seed Material

Samples of seed products are critical to ensure that there is a true representative of the sampled population under investigation. The sampling of seeds for this study was done in line with the criteria for seed sampling of the International Seed Testing Association (ISTA) rules for seed testing and was deployed for this activity (ISTA, 2010). Two (2) kilograms (kg) of seed samples were obtained using latex gloves from three (3) 50kg bags with similar batch codes and placed in sterile plastic bags for each seed sample. One (1) kg was used for lab analysis while the other half was left as a retention sample (ISTA.2010).

A total of 33 maize seed samples were obtained randomly from Otjozondjupa; 2016 (5), 2020 (2), Omusati; 2016 (6), Oshikoto; 2016 (2), Zambezi; 2020 (1), Kavango East; 2015 (8), and Kavango west; 2015 (9). A total of 10 wheat seed samples were randomly sampled from Omusati; 2016 (5), Kavango East; 2015 (3), and Kavango West 2015 (2).

Table 2: The samples of maize seeds, maize food and feed products, wheat seeds, and food products used in the analysis of GMs

Type	Sample no./Code	Type	Sample no./Code
Maize seeds	05/MS01/20	**Maize Food**	05/MF05/20
	13/MS03/20		
	13/MS04/20		
	11/MSV01/15		06/MF08/21
	12/MSK03/15		02/MF-AM01/15
	12/MSK02/15		02/MF-AM02/15
	12/MSK01/15		11/MF-AM04/15
	11/MS-GB01/15		11/MF-AM05/15
	11/MS-GB02/15		11/MF-AM08/15
	11/MS-GB03/15		11/MF-AM13/15
	11/MST01/15		03/MF-AM15/15
	12/MS01/15		03/MF-AM16/15
	12/MSU01/15		
	12/MSU02/15		
	12/MS03/15		
	11/MS01/15		
	11/M-SCS02/15		03/MF-AM18/15

	11/MS03/15		
	12/MS02/15		
	12/MS04/15		
	12/MS04/15	**Wheat food products**	11/WF-AM17/15
	12/WS02/15MA		11/WF-AM14/15
	11/WS02/15SH		
	11/WS03/15SHI		
	12/WS03/15SHA		
	06/WS09/16		
	06/WS10/16		
	06/WS08/16		
	06/WS06/16		
Wheat seeds	06/WS04/16		11/WF-AM09/15
	11/WS-V02/15		11/WF-AM10/15

DNA Extraction and Quantification

To determine the status of GMs, a wet bench research tool of biophysical data collection based on molecular biology and deoxyribonucleic acid (DNA) based tests was used (Gachet et al., 1998). Various methods have been developed to extract DNA from samples used in the detection, identification, and quantification of GMs in different plants, food, feed, and seed samples to ensure high DNA yield (Pacheco Coello et al., 2017). Cetyltrimethylammonium bromide (CTAB) is a common method used in extracting DNA, but there are also different DNA extraction kits (CTAB DNA Extraction Protocol of P. pruinosa v2 2017). For this study, all samples, including seed, food, and feed samples, were homogenized and the DNA was isolated using the GeneSpin DNA extraction kit (www.eurofins.de/kits), using the manufacturer`s reference material. Fluorescence Method is used mostly in determining the concentration of DNA. DNA was determined spectrophotometrically using a NanoDrop Spectrophotometer (Thermo Scientific). The quality of DNA was assessed at an absorbance ratio of A260/A280 (Pacheco et al., 2017). The DNA purity was confirmed by using agarose TBE gel electrophoresis (Aboul-Maaty & Oraby, 2019). The Gel was then visualized using the Micro doc.

GM Screen P35S/TNOS/CAMV

The DNA base technique using PCR has been proven to be the most reliable testing method (Rosa et al., 2016). Therefore, samples were isolated, screened using the Polymerase Chain Reaction (PCR) (a BIO-RAD CFX96) for their genetic content. After the DNA extraction, the first step is the screening phase, which establishes whether the samples contain GMO materials. This method uses specific assays that target constructs or genes that are used in the genetic modification process (both the NOS terminator and 35S promoter regions of the inserted DNA), see Figure 3.

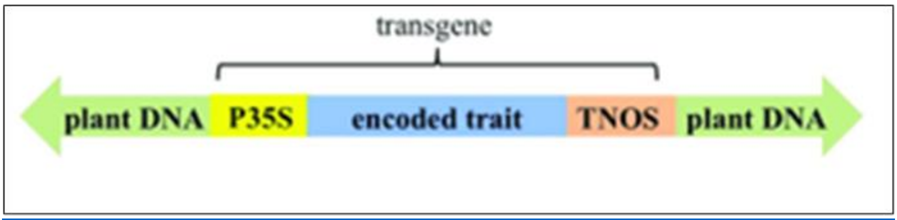

Figure 3: A genetically modified plant with a gene conferring a specific trait (in blue) expressed via the 35S promoter, P35S (in yellow), and the Nos terminator, TNOS (in orange)

PCR for screening of the adventitious presence of transgenic events 35S (Cauliflower mosaic virus (CaMV) and NOS (Agrobacterium tumefaciens plasmid nopaline synthase gene NOS) in the samples was done using the Eurofins GM Screen RT IPC (NR) 35S/NOS/ABII kit, https://www.eurofins-technologies.com/gmoscreen-rt-35s-nos-abiipc-lr.html. Certified reference materials, Internal Positive Control (IPC), and no template control were included in the PCR run. The PCR was run in a 12.5µl reaction mixture, 10 µl PCR mix, and 2.5 µl of the DNA template. The PCR was carried out in a BIO-RAD CFX96 Touch Real-Time PCR Detection System using initial denaturation (hold) at 95°C for 10 minutes, followed by 45 cycles of denaturation at 95°C for 15 seconds and annealing/extension at 60°C for 90 seconds.

RESULTS

GM Content Screening on Maize

Table 3 shows the GM content screening results on Maize food and feed obtained from Namibia`s sampled regions. The plus sign (+) denotes a positive occurrence of GM content while a minus (-) sign denotes a negative occurrence of GM content.

Maize food samples

Table 3 shows the GM content screening results on Maize food obtained from Namibia`s sampled regions; Ohangwena, Oshikoto and Kavango East (in 2015), Zambezi, Kavango East and Otjozondjupa (in 2020), Khomas and Omusati (in 2021). The results show that in 2015, out of 9 maize food samples tested for GM content from the three regions (Ohangwena, Oshikoto and Kavango East) only five samples tested positive; two (2) samples from both Ohangwena and Oshikoto region and one (1) sample from Kavango East. In 2020, six (6) samples from Zambezi, Kavango East and Otjozondjupa regions, five (5) samples tested positive for GM content; two (2) samples each from both Zambezi and Otjozondjupa region and one (1) sample from Kavango East region. In 2021, Khomas and Omusati region were sampled for GM content in food, and out of six (6) samples, only four (4) samples tested positive for GM content.

Table 3: GM content screening on maize samples

Maize food GM Screening Results; Positive (+) and Negative (-)				
YEAR	**REGION**		**FOOD**	
2015		**Total Samples**	**No. of positive samples (+)**	**No. of negative samples (-)**
	Ohangwena	2	2	0
	Oshikoto	3	2	1
	Kavango East	4	1	3
2020		**Total Samples**	**No. of positive samples**	**No. of negative samples**
	Zambezi	2	2	0
	Kavango East	1	1	0
	Otjozondjupa	3	2	1
2021		**Total Samples**	**No. of positive samples**	**No. of negative samples**
	Khomas	5	4	1
	Omusati	1	0	1
		21	14	7

Maize seed samples

Table 4 shows the GM screening results on Maize seed obtained from Namibia`s seed-sampled regions; Kavango East, Kavango West, Omusati, Otjozondjupa, Oshikoto and Zambezi) in three respective years (2015, 2016 and 2020). The results show that in 2015, out of 17 maize seeds sampled tested positive for GM content: two samples each from both Kavango East and Kavango West regions. While as in 2016 in 2016, 11 seed samples were obtained from three regions (Omusati, Otjozodjupa, and Oshikoto respectively). Two (2) samples from both Omusati and three (3) samples from Otjozondjupa tested positive for GM content. In 2020, only two regions were sampled (Zambezi and Otjozondjupa region). Out of the three seed samples tested, only one (1) seed sample tested positive from Otjozondjupa region.

Table 4: GM content screening on maize seed samples

Maize seed samples GM Screening Results; Positive (+) and Negative (-)				
YEAR	**REGION**	**Total Samples**	**SEED**	
2015			**No. of positive samples**	**No. of negative samples**
	Kavango East	8	2	6
	Kavango West	9	2	7
2016		**Total Samples**	**No. of positive samples**	**No. of negative samples**
	Omusati	6	2	6
	Otjozondjupa	3	3	0
	Oshikoto	2	0	2
2020		**Total Samples**	**No. of positive samples**	**No. of negative samples**
	Zambezi	1	0	1
	Otjozondjupa	2	1	1
		31	10	21

Maize feed samples

Table 5 shows the GM content screening results on maize feed samples obtained from Namibia`s sampled regions (Otjozondjupa region). The result shows that no GM content was detected on the sample tested in the year 2020.

Table 5: GM content screening on maize feed samples

Maize feed samples GM Screening Results; Positive (+) and Negative (-)				
YEAR	**REGION**	**Total Samples**	**SEED**	
2020			**No. of positive samples**	**No. of negative samples**
	Otjozondjupa	1	0	1

Percentage of GM content (in Maize food, feed products and seed) per region

Table 6 clearly shows that of the total food products in different regions, Ohangwena region has recorded the highest positive content of GM at 100%, followed by Khomas with 80%, while both Otjozondjupa and Zambezi have 66.7%, respectively. Mo of the samples was obtained from the Kavango East region, 84.6% of the samples did not contain GM content. Equally, both Otjozondjupa and Kavango West were the second regions with the highest number of samples, nine (9), however only 22.2% of the total samples tested positive for GM content.

Table 6: GM content (in Maize food, feed products, and seed) per region

Region	*Total Samples*	*No. of positive Samples*	*Positive samples (%)*
Kavango East	13	2	15.4%
Kavango West	9	2	22.2%
Khomas	5	4	80%
Ohangwena	2	2	100%
Omusati	7	2	28.6%
Oshikoto	5	2	40%
Otjozondjupa	9	6	66.7%
Zambezi	3	2	66.7%
Total	53	22	41,5%

GM Content Screening for Wheat

Wheat food sample

Wheat food samples were sampled in 2015 from Kavango East and Kavango West regions. A total of four (4) food wheat samples were obtained from the two regions and were tested for GM content. All the samples tested negative for GM content.

Table 7: GM content screening on wheat food samples

Wheat food samples GM Screening Results; Positive (+) and Negative (-)				
YEAR	**REGION**		**FOOD**	
2015		**Total Samples**	**No. of positive samples**	**No. of negative samples**
	Kavango East	4	0	4

Wheat seed sample

A total of twelve (12) wheat seed samples were obtained in 2015, from Kavango East and Kavango West regions, and from Omusati region in 2016. Three (3) seed samples were obtained from both Kavango East and Kavango West regions and one (1) seed sample from Omusati region, respectively. During the two-year period, all wheat samples obtained from the three regions tested negative for GM content.

Table 8: GM content screening on wheat seed samples

Wheat seed samples GM Screening Results; Positive (+) and Negative (-)				
YEAR	**REGION**	**Total Samples**	**SEED**	
2015			**No. of positive samples**	**No. of negative samples**
	Kavango East	3	0	3
	Kavango West	3	0	3
2016		**Total Samples**	**No. of positive samples**	**No. of negative samples**
	Omusati	5	0	5
		11	0	11

DISCUSSION

GM Content Screening on Maize

Maize food samples

This study asserted the presence of genetic modification in maize food samples in Namibia. Overall results established that there is presence of GM content in maize food samples; based on 21 food samples tested, 14 samples have shown a positive test for GM content. GM content in maize food is positive seeing that over 50% of Namibia's maize is imported from South Africa (Ala-Kokko et al., 2021) noted that white maize in South Africa is the only staple crop produced using GM cultivars. The detection of GM food became necessary to allow consumers to choose products and to comply with labelling regulations as per the Biosafety Act 7 of 2006 (Act No. 7, 2006). Even though the study asserted that there is positive GM content in some of the maize food products, it failed to indicate whether the maize food products that tested positive for GM were labeled, leaving a void for future research.

Namibia is not disallowing maize food product not to be imported as current new regulations allows maize food products with a determined 0.9% threshold amount for the presence of a GMO on maize products to be imported into Namibia under the permit condition. Seeing that most Namibian regions such as the Zambezi, Kavango East, Oshikoto, Otjozondjupa, and Omuasati had samples that tested positive is an indication that GM maize might have entered these regions not only from South Africa but could also be imported from other countries such as Botswana, Zambia, Zimbabwe, and Angola or vice versa. Thus, there is a need to conduct a qualitative study to determine the events present and possibly, the origin of these maize products. Moreover, considering the fact that historically, Zimbabwe only imports genetically modified-free corn, not because of food safety concerns. Conventional maize seed production concerns will also benefit from this study. GM maize seeds detected in the Zambezi region can co-mix with conventional maize seeds. For Namibia, this study has revealed a wide range of results requiring attention from the regulators to enforce labeling of GM maize products to ensure that importers are compliant and enforce the law to those planting GM seeds without approvals. South Africa and Eswatini are the only countries in the SADC region that grow GM crops at a commercial level and these crops include cotton, maize, and soybeans (ISAAA, 2019). However, the results from this study have found that 10 out of the 31 seed samples tested for GM content were positive. The fact that these seeds were gathered from local communities like the open markets in the far east and northern parts of Namibia raises the possibility that they may have come from nearby nations like Zambia, Angola, or Zimbabwe or vice versa.

Namibia has not approved GM seeds for growing but only for processing raising the question of whether the community members dealing in these seeds are aware of whether the seeds they were in position contained GM and whether these seeds were being sold for processing or for growing maize. A study done in South Africa on GM maize farmers where GM seeds are approved has shown that there is still a need to raise awareness about the social, economic, and environmental implications to farmers who elect to use GM seeds (Mahlase, 2017). Therefore, the lack of knowledge of the community members and farmers dealing in GM seeds may have serious social, economic and environmental implications in Namibia. According to the FAO, trace amounts of GM crops become mixed with non-GM food and feed crops by accident during field production as well as during processing, packing, storage, and transportation (FAO, 2014).

When maize seeds are planted close together and farmers reuse, trade, or mix maize seeds, the likelihood of gene flow by cross-pollination increases (Melinda & Hugo, 2003; Viljoen & Chetty, 2011). Therefore, the GM would spread and distributed during cross-pollination across adjoining fields as well as to neighboring nations if this community's members and farmers inside these regions are dealing in GM maize seeds without their knowledge. This would make it extremely difficult to maintain the proposed GMO-free zones within the African Model Law on Safety in Biotechnology. There are also some Namibian commercial farmers who do not want their crops to be contaminated by GMOs, because they would like to have access to perceived niche markets where GMOs are not accepted (Ministry of Agriculture, Water and Forestry, 2005).

The presence of GM maize seeds on the Namibian market also shows non-compliance with the fact that GM maize farming is not allowed without a permit. According to (Kruger et al., 2012), South African smallholder and commercial farmers are known to fail to comply with GM agricultural regulations. Kruger et al. (2012) further added that the grounds for non-compliance were the alleged lack of awareness in the field and this necessitated monitoring of maize farmers. According to Zehr (2010) education courses, incentives, and "rigorous" monitoring are used in India to encourage compliance among cotton producers. Seeing that there are Namibian farmers who are keen to produce genetically modified crops, while on the other hand, there are those that are opposed to the production of GMOs there is an urgent need for regulation in this area so that the interests of all stakeholders are protected (Ministry of Agriculture, Water and Forestry 2005). With the development of these regulations that are currently not available in Namibia, the relevant authorities can then come up with rigorous monitoring to encourage compliance among maize farmers. However, in the absence of those regulations there is a need to create awareness on the Biosafety Act 7 of 2006, (Act No. 7, 2006) especially in the various regions on the fact that GMO maize seeds are not allowed in the country without a permit as well as their current implications. The study also recommends that there is a need to ascertain the presence and quantity of GM content in maize seeds collected from various fields.

Maize feed samples

This study also evaluated the presence of GM content in maize feed sample. The results show that only one sample of maize feed that was analysed showed a negative GM content. The 1 sample of maize feed sample that was analysed in this study is not representative enough to ascertain the GM content in maize feed samples in the whole of Namibia. However, one could conclude that the seed that has tested positive once grown, the products produced from the harvest will be processed into food and feed (Grantina-Ievina et al., 2019). However, Terzi Aksoy & Ateş Sönmezoğlu, (2022) explained that in countries like Turkey, only accepted soybean and corn varieties are allowed to be used as animal feed within the framework of biosecurity law, but not for food consumption. However, in Namibia, GM Maize products are allowed by law for both animal feed and animal consumption under the permit condition. It is therefore important for law enforcement to monitor the law and continue testing GM content in feed to be able to ensure compliance similar to European Union (EU) best practices (Rostoks et al., 2019).

GM Content Screening on Wheat

Wheat food sample

According to Lal (2016), to meet the global food demand of the world population, which is estimated to be 9 billion by 2050, wheat production should grow by over 60% while enhancing or maintaining its nutrition. The current average global wheat production of about 3 tons per hectare is therefore well below the targeted production (Curtis & Halford, 2014). Therefore, effort must be put into wheat trait improvements that will be responsive to different environmental challenges (Borisjuk et al., 2019). Genetically modified wheat is part of the solution because in a world with abundant wheat, everything from bread and pasta to breakfast cereal and pizza crust would cost less. Overall results asserted that there is no presence of GM in maize food samples based on the 4 seed samples tested as 0 samples have shown a positive result for GM content. However, it is also necessary to conduct the same study with more representative samples and regions since the study's usage of wheat food samples, which was based solely on four samples from the Kavango East region, was not very representative.

What seed sample

According to Bedö et al. (2009), GM wheat with a significantly higher content of amylose has been developed within the framework of a joint research project carried out by the French cereal group Limagrain and the Australian Grain Research and Development Corporation (GRDC). The first wheat variety was modified at the University of Florida, USA with research funded by Monsanto (Borisjuk et al., 2019). In their study from 2016, Sheats and Jones claimed that GM wheat is not commercially accessible anywhere in the world. Despite extensive field testing and one wheat variety, Bioceres HB4 Wheat, which is drought tolerant is received regulatory permission from the Argentinean government in October 2020, no GM wheat has now produced commercially as of 2020 (Jeon, 2023; Ricroch et al., 2022). The most current research by Gilissen and Smulders (2021) still indicates that GM wheat has not yet reached the consumer market. Granja and Ueno (2023) have stated that the same wheat event HB4 was only approved for growing in Brazil in 2023. This indication is consistent with the findings of this study since it demonstrates that, based on the four seed samples that were assessed the overall findings indicated that there was no GM content in the wheat seed samples. This analysis confirming the negative PCR test for the presence of GM in Namibian wheat seed samples indicates that indeed, Namibia might be following other worlds in not using GM wheat seeds that have still not been produced commercially.

Jeon (2023) added that even though the Bioceres HB4 wheat received regulatory permission from the Argentinean government, the same government was worried about possible disruptions to agricultural trade if exports were found to be contaminated by an unapproved GM product. The Namibian government should therefore protect agricultural trade by continuing to enforce the regulation of GMs through monitoring and control to ensure that any wheat GM variety, HB4 enters the Namibian market should enter under the permit.

CONCLUSION

Regardless of the controversy surrounding GM crops, the planting of these plants continues to increase globally. Recently, a few GM-produced food and feed products have begun to show up on Namibian store shelves. Therefore, it is essential to enforce monitoring and ensure that everyone placing on the market either GM food or feed is doing it under the permit condition of such products are approved following due processes. In this study, different kind of 43 seed samples (maize (33), wheat (10)), 25 food samples (maize (21), wheat (4)), and 1 feed sample (maize (1), wheat (0)) obtained from 8 different regions of Namibia were analysed for their genetic content. The genomic DNA of all the samples was screened using the polymerase chain reaction (PCR) technique. PCR results show that 10 seed samples (maize (10), wheat (0)), 14 food samples (maize (14), wheat (0)), have tested positive for GM content.

Even though this was a qualitative (PCR screening) study it only asserted the presence of GM content in Food and feed products. The results have indeed indicated that there is GM content in various Namibian regions, and this is found in maize food and seed. The Namibian GMO products list different crops with transformed GMO events that must be regulated both feed and food products, under the Biosafety Act, 2006. However, since the law requires any product containing at least 0.9% GMOs to be labelled if a permit is granted, this study did not look at whether the food and feed products asserted to be containing GM content were labelled and whether their GM content is at least 0.9%. Therefore, it would be interesting to conduct a further study to quantify the amount of GM food and feed products found in the Namibian market. To date, Namibia has not approved GM seeds for growing and the fact that these seeds (that tested positive) were collected from the local communities in the regions in terms of the far east and northern part of Namibia there is a possibility that these seeds might have come from neighbouring countries such as Zambia, Angola or Zimbabwe.

Even though the study assessed the GM content of maize food products, it could not indicate whether or not the maize food products that tested positive for GM were labelled, leaving a void for future research. There is a need to create awareness of the Biosafety Act 7 of 2006, (Act No. 7, 2006) especially in the various regions on the fact that GMO maize seeds are not allowed in the country as well as their current implications. The study also recommends that there is a need to ascertain the presence and quantify the percentage of GM content in maize seeds (that have tested positive) collected from various fields.

The Namibian government should continue enforcing the regulation of GMs through monitoring and control while continuing to assess and manage the risks associated with the development and release of GM wheat food products when their presence is asserted in the global market.

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CONTRIBUTION TO THE FIELD STATEMENT

Namibia as a country introduced the Biosafety Act of 2006, and like many other nations, has implemented legislation requiring the labelling of genetically modified food and feed items (Biosafety Act No. 7, 2006). Limited research has been conducted in to establish whether food, feed and seed in the Namibia market contain genetically modified content. This study unpacks the research gap and opens up more research questions in this area.

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