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Detection of Genetically Modified Organisms (GMOs) in North America in Tofu: A Quantitative Experimental Case Study on the Accuracy of Non-GMO labels

Ziyu Han

Genetic modification refers to the reprogramming of an organism's genetic material (DNA) to achieve favorable attributes. As many were skeptical about genetically modified organisms (GMO), North America enacted a voluntary labeling law on foods containing no GMOs.
However, the lack of regulation by government authorities has allowed companies to utilize this legislation and deceitfully entice consumers with such labels to buy their products. To address this, a quantitative experimental case study on five different tofu products in North America, branded with or without a non-GMO label, using polymerase chain reaction was conducted.
Results revealed that three tofu products with a non-GMO label were incorrect, while two had inapplicable results. Furthermore, findings suggested more governance on non-GMO labels placed on tofu products. Although this study offered a more extensive insight on the accuracy of non-GMO labels on tofu products, further research is necessary to generalize results on a larger scale.

Keywords: Genetic modification, genetically modified organisms, non-GMO labeling, polymerase chain reaction, tofu

Introduction

Established in 2009, the Non-GMO Project Verified Label is recognized as North America's "most trusted seal for GMO avoidance" (The Non-GMO Project, 2016). However, in April 2018, the Canadian Food Inspection Agency (CFIA) announced that the Non-GMO Project Verified Label no longer necessarily means the product is GMO-free (Campbell, 2018). In fact, a report done by researchers Bain and Selfa in 2017 discovered that the differences between the terms "non-GMO" and "Organic" were not obvious to the average consumer, permitting companies to take advantage of the seal and falsely allure consumers to purchase their products. This not only breaches the trust between the Non-GMO Project and consumers, but also disrupts consumer purchasing behaviour and their understanding of a products' composition, directly impeding the objective of the Foods and Drugs Act and the CFIA, which states to "prohibit the labelling, packaging, selling or advertising of any food in a manner that is false, misleading or deceptive to consumers" (Canadian Food Inspection Agency, 2019).

The *Food and Drug Act* was authorized in 1997, three years after the inception of the first genetically modified organism, the Flavr Savr Tomato. Since then, humans have taken advantage of this revolutionary biotechnology to develop foods with enhanced and desired characteristics. This includes safer nutritional value, using fewer chemical fertilizers and pesticides

as stated by Monsanto, a multinational agricultural biotechnology cooperation (2019). This technique has played a key role in eradicating malnutrition and stimulating national food security (Olusegun & Olubiyi, 2017). However, adversaries of genetic modification argue that this technology poses a potential threat to the consumer as the product may include obscure allergens and toxins (Brady & Brady, 2003). Opponents further contend that genetic modification harms surrounding environments through cross-pollination (Brady & Brady, 2003). Others worry

about the ethics and the economic consequences regarding the control of agriculture through biotechnology companies (Radas et al., 2008).

Because of these concerns, legislation on the presence of GMOs in foods has been enacted worldwide, with the largest and most controversial one being mandatory labeling of GM products. In North America, there is significant evidence that a larger proportion of the population supports some form of GMO labeling on what they buy. Data for this information comes from a study conducted by Andree (2002), which indicates that more than 90% of Canadians supported the mandatory labeling of genetically modified foods. A study carried out by Radas et al. in 2055 respondents residing in America identified that about 83% wanted to see GM labels on their foods (Radas et al., 2008). However, despite consumers' preference and opinions, the labeling of GM foods is not mandatory in North America to date (Macdonald & Whellams, 2007). This created a perfect opportunity for food cooperations to legally be dishonest and mislead consumers with their labels (Macdonald & Whellams, 2007).

Given the status of the global food chain and given that both USA and Canada are two major producers and among the top five countries with the largest hectares of GM crops (International Service for the Acquisition of Agri-biotech Applications, 2016), it is likely that a significant portion of foods distributed in North America comprise of GMOs. Therefore, it is essential that the GM labels (and non-GM labels) on these products are accurate. The food product that will be used in this study to test the accuracy of labels is tofu. Tofu was chosen for the three following reasons. Firstly, the bulk of tofu products consists of a form of soybeans, which represents the number one genetically modified crop globally in quantity (James, 2014), accounting for nearly 50% of the world's GM planted areas (James, 2011). Secondly, the production process for tofu has insignificantly changed over the last 20 centuries, allowing for

consistent past research on tofu (Nikolić et al., 2017). Thirdly, as soybeans rank fourth in Canada's largest crop acreage, Canada is a main international exporter of soybeans, including tofu, exporting about two-thirds their soybeans to international food markets (SOY Canada, 2019).

Consumers have the right to know what is in their food and the right to select what they eat. Labels serve a critical role in assisting consumers to make conscientious choices as confirmed by research done by Bain and Selfa in 2017. As a result, this study plans to answer the question regarding how accurate non-GMO labels are on tofu labels sold in North American supermarkets. With the existing lack of concern and proper administration on GM food labeling in North American regulatory agencies, it is highly likely that mislabelling is present (Macdonald & Whellams, 2007). Using polymerase chain reaction, this study will attempt to verify a product's authenticity and potentially shed light on information for other researchers to build from.

Literature Review

In recent years, there has been an increase in debate and resistance against GMOs across the world since its introduction. This has resulted in a complete ban on GM food imports and cultivation in three countries and a requirement of mandatory labeling of GM foods in over 40 countries (Genetic Literacy Project, 2016). However, Canada's regulatory system, authorized by the CFIA, has approved 51 "plants with novel traits" and "novel foods" since 1995, most of which were genetically modified, with flexible laws on GM labeling and content thresholds (Andrée, 2002). As acknowledged from Macahilo's report on the GMO labeling laws in each country, the Canadian government offers minimal information about GM foods despite a large population of Canadians who want GM labeling on their food products (Macahilo, 2017). With this lack of knowledge, it is important to analyze the accuracy of non-GMF labels in North American supermarkets.

Non-GMO versus Organic

Since 2010, the longstanding market for non-GMO food products has expanded dramatically with two labels dominating the food market: The National Organic Program's USDA Organic Label and the Non-GMO Project Verified logo. The Project employs a product standard that aims to ensure that a product does not surpass its required level of GMO contamination (Greene, 2016), while USDA Organic is based on a process standard that requires the entire production process meets certain criteria to distinguish between GMO and Non-GMO foods. However, to the average consumer, the difference between the non-GMO butterfly logo and the organic label is not transparent and has generated significant confusion (Bain & Selfa, 2017). Megan Westgate, the executive director of the Non-GMO Project, stated that the

"relationship between non-GMO and Organic is probably the most politically sensitive thing we deal with" as hardly anyone can differentiate between the two terms (Bunge & Gasparro, 2015). The distinction between non-GMO and organic are essential to companies, specifically small businesses, as receiving the Non-GMO Project's or the USDA's organic approval take a long time and can come with an annual cost of thousands of dollars (Bain & Selfa, 2017). For other food companies, labels are viewed as a valuable way to improve their reputation and credibility as socially responsible and can help evade activist pressure (Bartley et al., 2015).

However, as reported by researchers Timmermans and Epstein, labeling acts as a powerful technique to mobilize conscientious consumers and encourage individuals to control their lives (2010). Other researchers, Bunge and Gasparro, found that consumers, despite having a lack of insight and education on GMOs, were more influenced and placed a higher value on specifically the non-GMO label than the secured organic label even though the non-GMO label offered more room for manipulation (2015). However, according to Professor McFadden, some companies are utilizing this consumer desire for a label as a marketing strategy, with large food cooperations taking advantage of consumers and including futile claims to their products that never contained GMOs in the first place (2018). McFadden believes that the purpose of labeling for these cooperations is more about marketing and stigmatization rather than providing consumers with helpful material to aid in their decision-making (2018). To minimize consumer confusion and deception, researchers Bain and Selfa stress the USDA Organic label should be the sole non-GMO label on food products to minimize consumer confusion, believing that the Organic label is based on a comprehensive, holistic set of environmental approaches while the Non-GMO Project label is dependent on a test (2017). Therefore, it is imperative that consumers are informed about

the differences between the Non-GMO Project Label and USDA Organic Label, if both leading trademarks remain, to ensure clarification for consumers in their purchases.

Labeling Discrepancy

With insufficient information provided on the term "non-GMO," companies often take advantage of the label and misinform consumers into thinking their product is healthy (Kilman, 2001). A recent sample of soybeans labeled as "non-GMO" from the Yves Canadian Veggie Bacon, a Canadian cooperation selling natural foods, was found to have been about 40% genetically modified, according to the Wall Street Journal. In their analysis of non-GMO labels in companies across North America, researcher Callahan and Kilman suggested these labels are often inaccurate due to the lack of government agencies that verify the accuracy of such labels, concluding that "enforcement is left to individual countries, most of which make little or no effort to test consumer products" (2001). Limiting to only government departments in North America, researcher Heslop confirmed that Federal organizations in North America have loosely regulated such products, assessing GM foods as "substantially equivalent" to non-GM foods and not enacting any special vetting on them prior to market introduction (2006). Several researchers gave suggestions to these cooperations. For instance, Bain et al., in their analysis on GMO contaminated landscapes, proposed that developing thresholds and product testing for GMOs provides more transparency for consumer trust and drawing on expect discourses and farming practices, where the credibility for standards is based on appeals to scientific norms and values, establishes legitimacy for such measures (2017). In addition, researcher

Holly from the Canadian Medical Association asserts that "smarter inspection, not more inspection" will be necessary to achieve greater truthfulness, specifically proactive detection of deficiencies and insightful analysis of system operations (2010). However, these extra implementations will be costly, for both consumers and state governments, and dissuade companies from enacting such policies (Grobe, 2004). According to Huffman, many companies refuse to label their food products, because of the cost, specifically the expense of testing, segregating crops, and the monitoring of the authenticity of such labels (2004). Critics argue that the Project offers already enough transparency as it specifically indicates "Non-GMO" and displays the threshold for GMO contamination (Bain & Selfa, 2017). However, the reliance on testing and thresholds implies there is some level of GMO contamination, and therefore products may not actually be non-GMO. In his article, Mol emphasizes that "value chain transparency will only execute its transformative powers towards sustainability … when those meant to use the disclosed information have access to and literacy regarding this information" (2015). More consistent reporting and research is necessary for consumers, including farms, buyers, food producers, scientists, and lawmakers, to make decisions (Steiner & Bird, 2008). This confirms the necessity of more testing and reliable labeling to give consumers an informed judgment.

Labeling Regulation

In 1999, government departments asked The Royal Society of Canada to create the Expert Panel on the Future of Food Biotechnology to evaluate and monitor Canada's ability to regulate GMOs. In 2001, the Expert Panel criticized the existing system and formed 53 recommendations to reform the regulatory system (Canadian Biotechnology Action Network, 2015). Up until today, only two recommendations have been fully implemented. To confront and prevent companies from freely pasting a "Non-GMO" label on their food products, the Canadian General Standards Board ratified a national standard for the voluntary labeling and advertising of foods that are and are not products of genetic modification in 2004 (Public Services and Procurement Canada, 2004). However, the Non-GMO Project established a standard on an inaccurate definition of a GMO, allowing any company to use their logo as a seal for GMO avoidance, circumventing Canadian laws (Campbell, 2018). Additionally, the CFIA plays a role in monitoring Canadian food labels under the standards of the *Food and Drug Act* and *Consumer Packaging and Labeling Act* to ensure truthfulness (Louden & Macrae, 2010). Once the CFIA certifies a specific GM crop, it is classified as a plant with the novel trait (PNT) and undergoes an environmental inspection. The assessment contains approximately ten scientists that check information and raw field test statistics on the PNT from data provided by the applicant, published documents, technical papers, or international reports. However, problems do exist in the process. For example, the CFIA does not evaluate the accuracy of the assessment, as Researcher Andree says, nor does it assess the long-term, cumulative effect of the GMO (2002). Other professionals state that the information is also concealed from the public, illustrating the lack of transparency in the regulation of labeling in Canada (Canadian Biotechnology Action Network, 2015). This shows that critical improvement in Canada's labeling regulation system to ensure better accuracy of labels.

Method

To answer the question, a quantitative experimental case study and then a thematic analysis was done. The concerns emphasized in the previous section will be analyzed using data from samples of tofu produced in North America and stamped with the non-GMO labels. Five different samples of tofu were chosen for this experiment, two of which had the non-GMO Project Verified label, another two which had their own non-GMO labels, and one that had no label.

All trials will be done by polymerase chain reaction (PCR). A PCR instrument was selected in this study for the following purposes: firstly, the PCR technique repeatedly copies DNA samples of products to ensure detection, quantitation, and accuracy (Foodchain ID, 2018). This amplification confirms the sensitivity and specificity in the PCR detection method. Secondly, a PCR approach is practical, reproducible and sensitive enough to detect up to 0.1% of GMOs in food products (Alasaad et al., 2016). Thirdly, the PCR test detects for a promoter from the Cauliflower Mosaic

Virus (CMV 35s), an icosahedral virus, and an insecticide gene extracted from *Bacillus thuringiensis* (Cry1F), in which a substantial number of transgenic crops, including tofu, have (Cankar et al., 2005).

Data Collection

Following Al-Salameen et al.'s model (2012) on the detection of GMOs in Kuwait's food market, five different brands of tofu were purchased to be examined with PCR. A positive test control sample was present that provided an example of a successful genomic DNA purification for soybean extractions. Two kits were bought, with each kit allowing for a maximum of 25 reaction trials. Five trials were used as a test-run and thirty trials were used to analyze all tofu product. The selected tofu were Sakura Fresh Silken Tofu, House Foods Premium Firm Tofu, Pulmuone Organic Tofu, T&T Soft Tofu, and Sunrise Premium Soft Tofu.

DNA Extraction

Before beginning the procedure, 14 tubes of 800μL NaCl solution, 13 tubes of 110μL of Universal DNA Buffer, isopropanol, and 70% ethanol were prepared. Additionally, 200μL of DNA Extraction Buffer was mixed with each tube of Proteinase K and placed back into the DNA Extraction Buffer container as the Proteinase K dissolved. In each trial, a small piece of tofu was extracted from the entity, smashed and transferred to a microcentrifuge tube using a micropipette until it reached the 0.1 mL mark. 400μL of DNA extract buffer was added to the tube and ground with a micropestle until no sizable pieces remained. Once finished, the food sample flicked to mix components together and incubated at 56 °C for 15 minutes. 300μL of NaCl solution was added to the tube and flicked for 30 seconds to mix solutions. The food sample was then centrifuged at full speed for 5 minutes. Once completed, the supernatant was transferred into a new microcentrifuge tube using a micropipette. Equal volume of room- temperature isopropanol was inserted into the supernatant to precipitate the DNA. The tube was incubated at room temperature for five minutes and then centrifuged at full speed for another five minutes. Once finished, the supernatant was removed, leaving a small DNA pellet at the bottom of the tube. The pellet was then washed by adding 500μL of 70% ethanol to the tube and centrifuged at full speed for 2 minutes. The supernatant was removed and the tube, left with the pelleted DNA, was dried for 5 minutes. Afterwards, the pellet was resuspended in 50μL of Universal DNA Buffer by pipetting up and down several times and placed in ice.

PCR Amplification

Next, 20μL GMO primer mix (yellow), 5μL of extracted DNA and a PCR EdvoBead Plus was added to a 0.2 mL PCR tube and then mixed until everything completed dissolved into a light orange hue. The tube was centrifuged for a few seconds to obtain the sample at the tube's bottom and then the DNA was amplified using PCR by (1) denaturation 94 °C for 5 minutes; (2) 94 °C for 60 seconds, 58 °C for 60 seconds, and 72 °C for 60 seconds for a total of 35 cycles; (3) final extension 72 °C for 10 minutes. Once completed, the tube was placed in ice.

Electrophoresis Separation

Afterwards, agarose powder was mixed with 1X TAE buffer in a 250 mL flask and boiled in a microwave until the solution completely dissolved. After the solution cooled down to 60 °C, SYBR Safe was added and swirled. The agarose solution was poured into the gel-casting tray and watched until the gel solidified. The gel was then transferred to the electrophoresis chamber and submerged with 1X TAE Buffer. After 40 minutes, the gel was transferred into a transilluminator and the results were photographed.

Results

Each of the following six pictures show the results of the agarose gel electrophoresis of genomic DNA from five samples of extracted tofu. As shown, there were seven lanes in each photo. The first lane of every photo had the 100-base pair ladder. The 100-base pair ladder begins at the bottom, with each band 100 base pairs larger than the previous band. The second lane of each photo had the GMO positive control, except for Figure 2, that acts as a confirmation for the PCR reac-

Figure 1: Agarose gel electrophoresis for SunRise Tofu. Lane 1 represents the 100-base ladder. Lane 2 represents the GMO positive control. Lane 3 to lane 7 represents the five tofu samples.

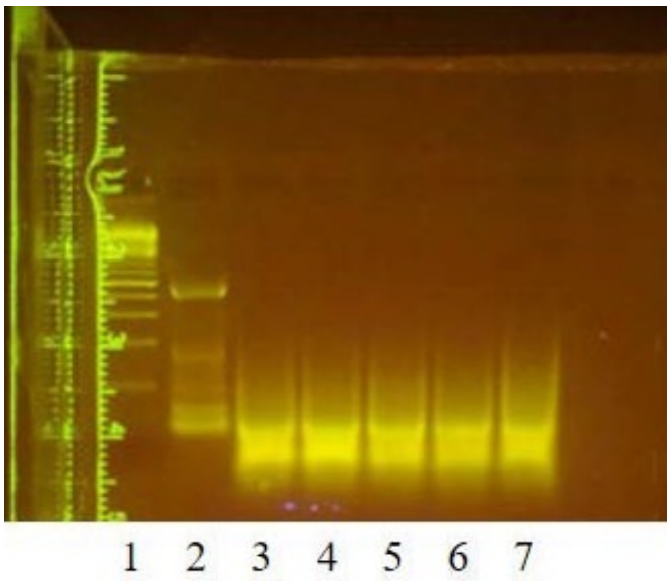


Figure 2: Agarose gel electrophoresis for House Foods Tofu. Lane 1 represents the 100-base ladder. Lane 2 to lane 6 represents the five tofu samples.

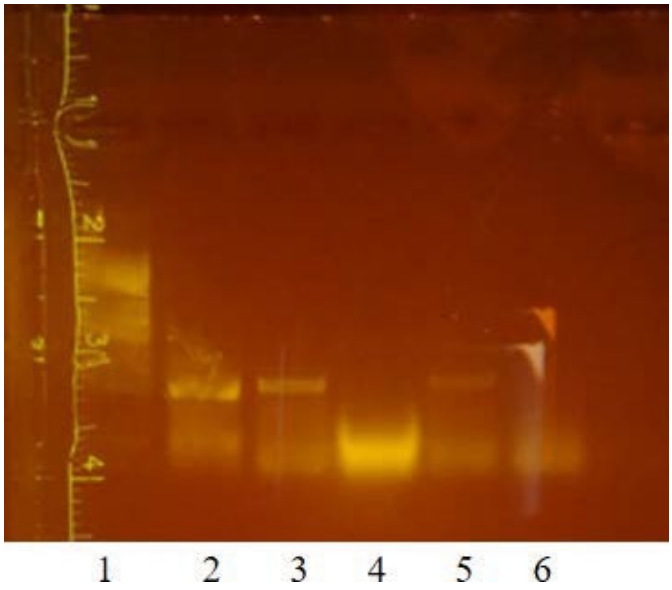


Figure 3: Agarose gel electrophoresis for T&T Supermarket Tofu. Lane 1 represents the 100-base ladder. Lane 2 represents the GMO positive control. Lane 3 to lane 7 represents the five tofu samples.

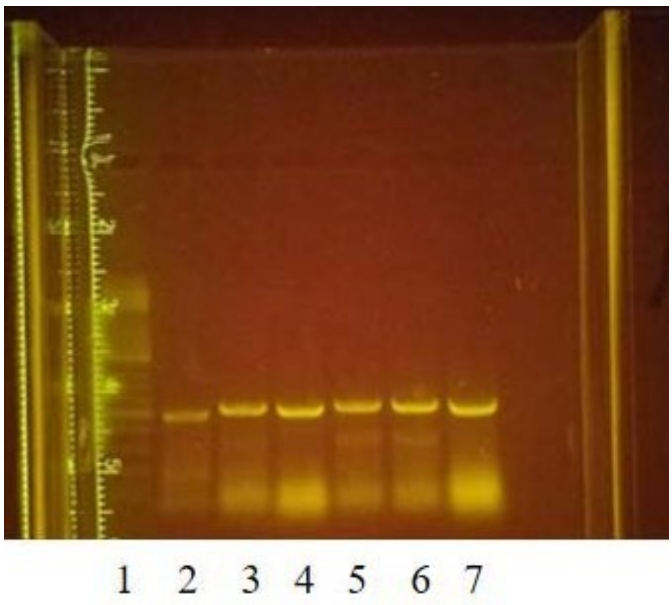
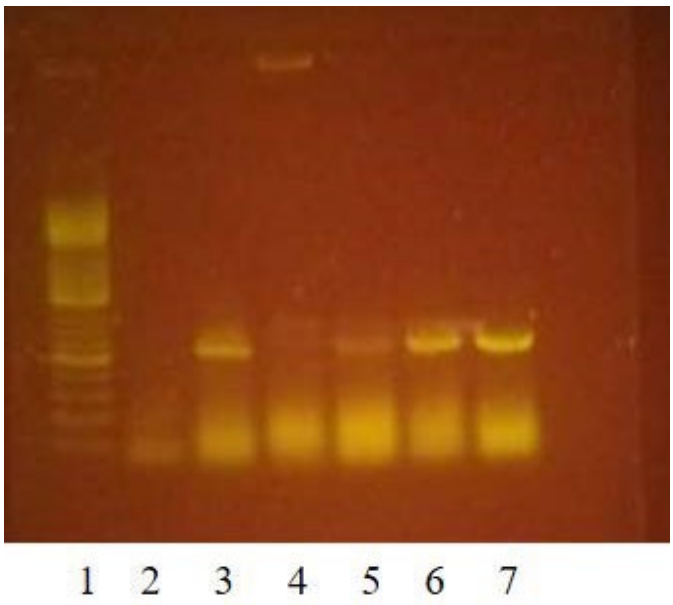


Figure 4: Agarose gel electrophoresis for Korean Food Trading LTD Tofu. Lane 1 represents the 100-base ladder. Lane 2 represents the GMO positive control. Lane 3 to lane 7 represents the five tofu samples.



tion and indicates where bands of DNA (Plant DNA, CMV 35s, and Cry1F) should have generally traveled. According to the Edvotek kit, plant DNA should be near 500 base pairs, CMV 35s should be near 200 base pairs, and Cry1F should be near 125 base pairs.

The remaining five lanes consisted of samples of the specified tofu product except for Figure 6, which included a sample of each of the five tofu products in every lane. This was done to summarize the results and get a comparison of the DNA in the tofu products.

Figure 5: Agarose gel electrophoresis for Sakura Tofu. Lane 1 represents the 100-base ladder. Lane 2 represents the GMO positive control. Lane 3 to lane 7 represents the five tofu samples.

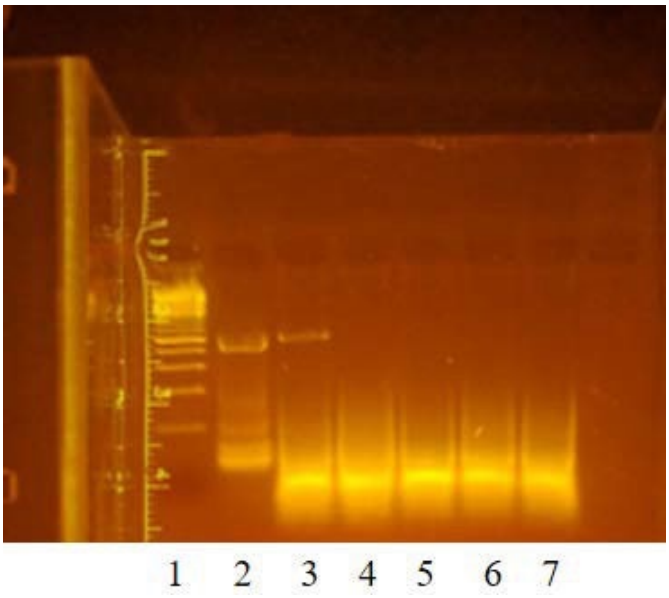


Figure 6: Agarose gel electrophoresis for blitz of all 5 different tofu samples. Lane 1 represents the 100-base ladder. Lane 2 is the GMO positive control. Lane 3 is Korean Premium Tofu. Lane 4 is SunRise Soft Tofu. Lane 5 is Sakura Fresh Silken Tofu. Lane 6 is HouseFoods Firm Tofu. Lane 7 is T&T Soft Tofu.

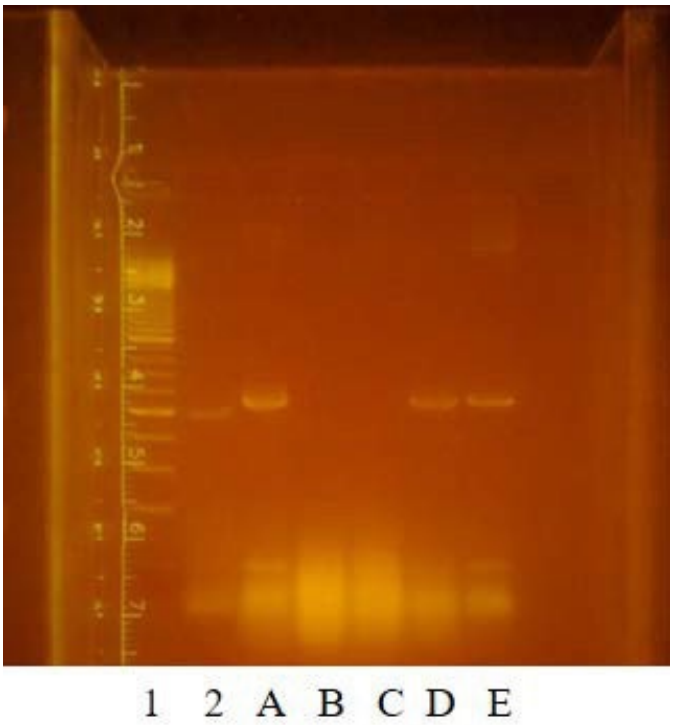


Table 1 (right): Table of all 25 samples used during the experiment. Illustrates the sample name, the manufacturing company, where it was processed, the label(s) on the product, and the length of DNA fragments after electrophoresis. N/A means no band was detected

Sample No.	Sample	Company of Production	Place of Origin	Type of Non-GMO/Organic Label (as shown on product)	Length of Plant Chloroplast Gene (bp)	Length of Cauliflower Mosaic Virus Gene (bp)	Length of Bacillus Thuringiensis Gene (bp)
1	SunRise Soft Tofu	SunRise Soya Foods	Canada	No Label	N/A	N/A	N/A
2	SunRise Soft Tofu	SunRise Soya Foods	Canada	No Label	N/A	N/A	N/A
3	SunRise Soft Tofu	SunRise Soya Foods	Canada	No Label	N/A	N/A	N/A
4	SunRise Soft Tofu	SunRise Soya Foods	Canada	No Label	N/A	N/A	N/A
5	SunRise Soft Tofu	SunRise Soya Foods	Canada	No Label	N/A	N/A	N/A
6	HouseFoods Firm Tofu	House Foods American Production	United States of America	Non-GMO Project Verified Label	505	N/A	130
7	HouseFoods Firm Tofu	House Foods American Production	United States of America	Non-GMO Project Verified Label	510	N/A	120
8	HouseFoods Firm Tofu	House Foods American Production	United States of America	Non-GMO Project Verified Label	N/A	N/A	120
9	HouseFoods Firm Tofu	House Foods American Production	United States of America	Non-GMO Project Verified Label	510	N/A	120
10	HouseFoods Firm Tofu	House Foods American Production	United States of America	Non-GMO Project Verified Label	510	N/A	120
11	T&T Soft Tofu	T & T Supermarket	Canada	Non-GMO Project Verified Label	500	N/A	125
12	T&T Soft Tofu	T & T Supermarket	Canada	Non-GMO Project Verified Label	500	N/A	125
13	T&T Soft Tofu	T & T Supermarket	Canada	Non-GMO Project Verified Label	500	N/A	125
14	T&T Soft Tofu	T & T Supermarket	Canada	Non-GMO Project Verified Label	500	N/A	125

15	T&T Soft Tofu	T & T Supermarket	Canada	Non-GMO Project Verified Label	498	N/A	125
16	Korean Premium Tofu	Korean Food Trading LTD	United States of America	Own Non-GMO Label	500	N/A	120
17	Korean Premium Tofu	Korean Food Trading LTD	United States of America	Own Non-GMO Label	500	N/A	125
18	Korean Premium Tofu	Korean Food Trading LTD	United States of America	Own Non-GMO Label	500	N/A	125
19	Korean Premium Tofu	Korean Food Trading LTD	United States of America	Own Non-GMO Label	500	N/A	125
20	Korean Premium Tofu	Korean Food Trading LTD	United States of America	Own Non-GMO Label	500	N/A	120
21	Sakura Fresh Silken Tofu	Sakura	Canada	Own Non-GMO Label	500	N/A	N/A
22	Sakura Fresh Silken Tofu	Sakura	Canada	Own Non-GMO Label	N/A	N/A	N/A
23	Sakura Fresh Silken Tofu	Sakura	Canada	Own Non-GMO Label	N/A	N/A	N/A
24	Sakura Fresh Silken Tofu	Sakura	Canada	Own Non-GMO Label	N/A	N/A	N/A
25	Sakura Fresh Silken Tofu	Sakura	Canada	Own Non-GMO Label	N/A	N/A	N/A

Analysis

In all six figures shown above, it is evident that the agarose gel is separated into three main sections: the first for the 100-base ladder (beginning from the bottom), the second for the GMO positive control, and the third for the tofu samples. The GMO positive control displays three distinct bands: a 500 bp band to represent the plant chloroplast gene, a 200 bp band to represent the CMV 35s promoter, and a 125 bp band to indicate the Cry1F gene. In this experiment, the results of five different types of tofu products were compared after undergoing electrophoresis to show the nature of the non-GMO Project Verified Label in the tofu industry. Five contrasting tofu were used: SunRise Soft Tofu (Figure 1), HouseFoods Firm Tofu (Figure 2), T&T Soft Tofu (Figure 3), Korean Premium Tofu (Figure 4), and Sakura Fresh Silken Tofu (Figure 5).

Figure 1 shows the gel electrophoresis for SunRise Soft Tofu. As shown, the only bands that were available were under the first bp band (100 bp). These bands were also very similar in traveling distance of about 42 mm and base pairs of about 0. This meant that it

Table 2: Results of the final blitz of 5 tofu samples. Illustrates the sample name, the manufacturing company, where it was made, the label(s) on the product, the length of DNA fragments after electrophoresis, and the distance travelled by the DNA. N/A means no band was found.

Sample No.	Sample	Company of Production	Place of Origin	Type of Non-GMO/Organic Label (as shown on product)	Length of Plant Chloroplast Gene (bp)	Length of Cauliflower Mosaic Virus Gene (bp)	Length of Bacillus Thuringiens is Gene (bp)	Distance Travelled by bands (Plant DNA, CMV 35s, Cry1F) in mm
A	Korean Premium Tofu	Korean Food Trading LTD	United States of America	Own Non-GMO Label	505	N/A	125	42/0/62
B	SunRise Soft Tofu	SunRise Soya Foods	Canada	No Label	N/A	N/A	N/A	0/0/0
C	Sakura Fresh Silken Tofu	Sakura	Canada	Own Non-GMO Label	N/A	N/A	N/A	0/0/0
D	HouseFoods Firm Tofu	House Foods American Production	United States of America	Non-GMO Project Verified Label	505	N/A	110	42/0/64
E	T&T Soft Tofu	T & T Supermarket	Canada	Non-GMO Project Verified Label	510	N/A	115	41/0/63

did not have the CMV 35s promoter, which occurs at around 200 bp, nor the Cry1F gene, which occurs at around 125 bp. However, it can also be observed that the PCR did not detect any plant chloroplast in SunRise Tofu as indicated in Table 1. This meant that the results for this tofu were invalid because it had no useable DNA.

Figure 2 displays the gel electrophoresis for House-Foods Firm Tofu. As shown, the plant chloroplast was detected in four of the five tofu samples (Table 1). Furthermore, all five samples were shown to have DNA bands near the 125 bp Cry1F band location. The first lane consisted of a band around 130 bp, while the other four lanes had bands of about 120 bp as listed in Table 1.

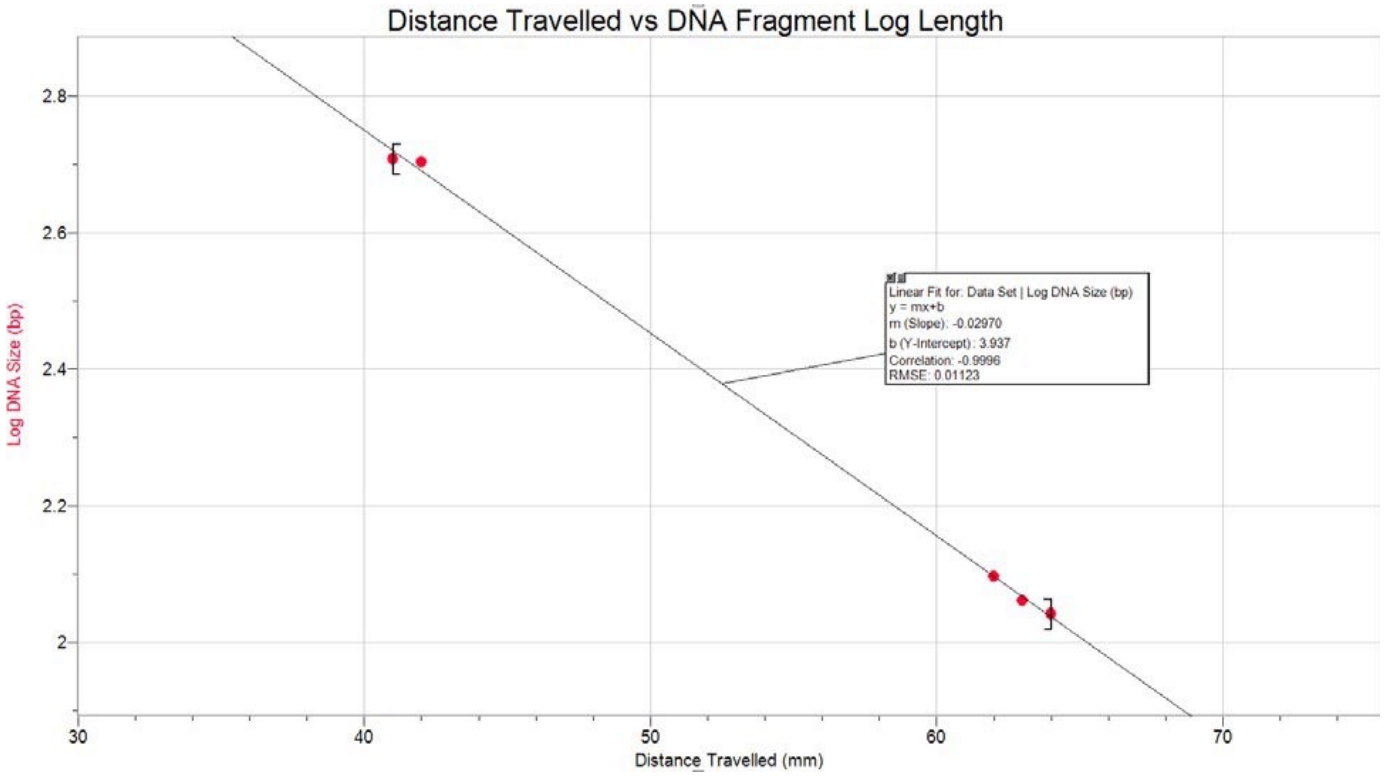
Figure 3 illustrates the gel electrophoresis for T&T Soft Tofu. As shown, all tofu lanes had clear plant chloroplast band and a Cry1F band. Some of the lanes also had bands that were approximately 400 bp (Table 1). Furthermore, all bands have a similar mitigated distance of about 55 mm (Figure 3).

Figure 4 shows the gel electrophoresis for Korean Premium Tofu, which has a similar trend to that of T&T Soft Tofu. Apart from Lane 4, all other four lanes of Korean Premium Tofu displayed two distinct bands, one of which highlights the plant chloroplast gene and the other which depicts the Cry1F gene present in the tofu. Lane 3 and Lane 7 appeared to have a Cry1F band of about 120 bp while Lane 4, 5, and 6 presented a Cry1F band of about 125 bp.

Figure 5 features the gel electrophoresis for Sakura Tofu, which is similar to that of SunRise Soft Tofu. Only Lane 3 indicates a plant chloroplast gene in Sakura Tofu while the other lanes consist of bands not in line with the plant chloroplast or Cry1F gene. Therefore, there is not enough physical evidence to justify that Sakura Tofu consists of no GMOs and can be considered "unknown." It is evident that no tofu product tested for the CMV 35s gene.

After the 25 samples were tested and photographed, a blitz of the five tofu products went through a final gel electrophoresis alongside each other as shown in Figure 6. As seen in Table 3, Korean Premium Tofu (Lane 1), Housefoods Firm Tofu (Lane 4), and T&T Soft Tofu (Lane 5) all had GMOs ingredients in them, while the remaining two tofu products had no gene detected by the PCR, confirming and supporting the results obtained from the first 25 trials of tofu in Table 2.

Figure 7: A semi-log graph that illustrates distance mitigated by DNA fragments of all 5 final blitz tofu samples in 2.0% agarose gel.



With these results, a semi-log graph with a relationship between the distance mitigated in millimeters (X-axis) and DNA fragments base pair lengths (Y-axis) was constructed as shown in Figure 7. The graph allows us to make an accurate estimate of how large an unknown band is just by knowing how far it has traveled. The points were a collection of the distance traveled by all the DNA fragments in Table 2. As shown, there is a negative correlation between the distance traveled and the Log DNA Length, illustrating that the greater the size of the DNA, the less distance it travels.

Discussion

Although the results produced in this experiment were in line with the starting hypothesis, it did offer some unexpected outcomes. It was predicted that there was a high chance of the non-GMO labeled tofu products to contain GMOs due to the poor supervision on these labels. From the results shown in Figure 1 to Figure 6, it is evident that the hypothesis regarding company mislabeling was experimentally proven correct. Out of the five tofu products that were used for the experiment, three were shown to have contained GMOs despite having a non-GMO label. Surprisingly, out of all the 25 samples of tofu that were conducted in the experiment, none had shown to have contained the CMV 35s promoter gene. Furthermore, the remaining two products showed no results for any DNA genes when using the PCR, not even the plant chloroplast gene. One possible explanation for this is due to the fermentation process in the creation of tofu. Fermentation involves chemically breaking down substances through using microorganisms (Alford et al., 1999). In a study conducted by Walker et al. on DNA genes and wine fermentation, they mentioned that fermentation caused nutrient depletion, suggesting that the fermentation process may have disturbed the DNA in the tofu and broke it down, making it undetectable by the PCR (Walker et al., 2014). Furthermore, the results in the experiment were unexpected as both products labeled with the non-GMO Project Verified label, an acclaimed seal in both Canada and the United States, turned out to contain GMOs.

Limitations

After concluding the research process and gathering the findings, there are several limitations that need to be considered. The largest limitation lies in the Edvotek PCR kit used to analyze the tofu products. The PCR instrument that was purchased was limited to detecting up to only two primers that would illustrate the presence of GMOs, a promoter of CMV 35s or an insecticide gene extracted from Cry1F. Therefore, if the product consisted of any other GMO gene, the PCR kit would not have picked it up, potentially creating some discrepancies in my results. Furthermore, the supplies provided in the two purchased kits allowed for a maximum of 50 test trials. However, due to human error and time, only 30 trials were effective and applicable. This added a limitation on the number of tofu available to test while still maintaining enough results for each product. Given this limitation, the study may have missed opportunities for a more extended analysis. However, because the study exemplified evidence of some non-GMO labeled tofu products to contain GMOs, the results still offer crucial insight into the deception of food companies.

An additional limitation was the scope of the study. Because it was narrowed down to specifically tofu, the findings were unable to be generalized to all foods in North America, and therefore, limiting the implications of my conclusions.

Lastly, to make tofu, it must undergo a fermentation process. This would have broken down the DNA genes in tofu and made it undetectable. It is possible that this risk in using tofu led to inaccurate results.

Future Research

The results and conclusions for this experiment have the potential for future research to address these limitations. Since the results of the DNA found after electrophoresis were mostly blurry and unclear, reproducing this experiment using 1X TBE buffer instead of 1X TAE buffer can possibly lead to a more profound and clearer separation of DNA bands as TBE is a better conductive medium than TAE and used for fragments that are less than 2kb (Oswald, 2017).

TBE buffer would also produce a higher resolution for small DNA fragments than TAE (Miura et al., 1999). Furthermore, since the tofu products tested were strictly made in Canada or the United States, replicating the experiment with tofu made in a diversity of different countries can lead to a greater range of results and the opportunity for further analysis. Or, since tofu has the potential risk of undergoing fermentation, repeating this experiment with a variety of food products (corn, papaya, etc.) with the non-GMO Project Verified Label can indicate a more generalized result that can be applicable and better test for the accuracy of non-GMO labels.

Conclusion

The results of this experiment clearly summarized that consumers are buying “non-GMO” products still containing GMOs that were initially said to not have. Therefore, the implications of this study are clear. Authorities across North America must be monitored and make a greater effort at regulating what gets placed on the foods distributed throughout the continent. Furthermore, with Canada and the USA being two leading producers in biotech groups (James, 2011), it can also be concluded that this sort of false advertising or mislabelling must also occur on products other than tofu. The use of GMOs across the world is rising exponentially, either because of the opportunity to create a near-perfect food product at a cheap cost or save millions of lives from hunger, malnutrition, and starvation (Toft, 2012). Through enforcing these applications in the future, consumers will be given the insightful understanding and truthful information they deserve for what they eat, just like what the Canadian Federal Inspection Agency has promised to do.

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