Public Health Risks and External Food Safety in the Canadian Marketplace

Nikita Tchou-San-Da[1], Dale Chen[2], Chris Piesik[3]
1. Nikita Tchou-San-Da, B. Tech Student, School of Health Sciences, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G 3H2.
2. Dale Chen, Supervisor, School of Health Sciences, British Columbia Institute of Technology, 3700 Willingdon Ave, Burnaby, BC V5G 3H2.
3. Contributor*, FoodAssure Laboratory Ltd*., 1960 Pandora St, Vancouver, BC V5L 0C7.

Background:
The expansion of the food industry has increased the demand for diverse food products, which poses new challenges to food safety. The production, transportation, and handling of food products from various sources and countries can increase the likelihood of foodborne illness outbreaks and product contamination. Regulatory developments, such as the Hazard Analysis and Critical Control Points (HACCP) systems, have helped mitigate trade barriers and ensure a safe food supply chain. However, different food safety regulations and standards in importing countries can make it challenging to determine if imported goods are as safe as domestically produced ones. Total coliform testing is a commonly used indicator of potential fecal contamination in food products. Thus, this study aims to provide a comparative analysis between a domestic and an international pasteurized dairy product falling under category 3 to provide literature and the means to mitigate safety risks.

Methods:
Firstly, samples were tested for water activity using a Pawkit water activity meter and standardized procedures were followed. Secondly, a commercial lab was hired to perform the total coliform testing under the MFHPB-14 standardized method. Finally, a statistical analysis was performed to determine if an external dairy market product under category 3 is satisfactory or comparative to a domestically manufactured one.

Results:
The study results indicate no significant difference in the mean total coliform levels between domestically produced cheese curd snacks and imported cheese curd snacks. Both groups had a mean value of less than 10 CFU/g; no detectable differences were found in their respective samples. The statistical method used in the study could not determine any variability between the two datasets, and hypothesis testing, and probabilities of alpha and beta errors may not be relevant. However, assuming that the two datasets are identical, a value of zero for both datasets indicates that there is no difference between the means of the two groups being compared. The study was not able to find sufficient evidence to reject the null hypothesis, and it was concluded that there is no difference in the mean total coliform levels in pasteurized imported dairy cheese curd snacks compared to the mean coliform levels in domestic pasteurized dairy cheese curd snacks.

Conclusions:
The present study has investigated the effectiveness of the MFHPB-14 standardized method in quantifying the total coliform counts of domestic and international cheese curd snack samples. The results obtained were found to be below the level of detection, indicating that the method failed to quantify the samples under investigation. Based on these findings, it is concluded that both domestic and international cheese curd snack samples are within the satisfactory range and are indistinguishable with respect to total coliform counts. It is important to note that this study only examined a limited number of category 3 cheese curd snacks available in the Canadian marketplace and may not be representative of the broader market; however, it implies that the products in our Canadian marketplace undergo stringent controls for the safety of our consumers.

Keywords: Dairy, Category 3, Water activity, food safety, total coliforms

Introduction:

The food industry is constantly expanding, driven by the ever-growing demand for diverse food products from both local and international sources. While this expansion provides consumers with a wide variety of food choices, it also introduces new challenges to food safety (Buzby, 2003). The production, transportation, and handling of food products from various sources and countries can increase the likelihood of foodborne illness outbreaks and product contamination (CDC, 2021).

These challenges have implications for the food safety standards of internationally manufactured food products, especially when importing countries have different food safety regulations and standards. However, regulatory developments, such as voluntary information provisions for production practices and certifications, have helped mitigate trade barriers and enable food product trade among countries, which ensures competitive pricing and an ample supply of safe food (Buzby, 2003). On the other hand, to ensure food safety, some regulations have imposed new or more stringent process standards, including the Hazard Analysis and Critical Control Points (HACCP) systems (Buzby, 2003). This is because it is challenging to determine if imported goods are as safe as domestically produced ones. Considering the aforementioned challenges and regulatory developments, it is crucial to address recent product sanitation quality concerns. One potential approach is to conduct a comparative analysis between a domestic and an international pasteurized dairy product falling under category 3. This analysis can provide a valuable means to mitigate safety risks by utilizing total coliform testing, a commonly used indicator of potential fecal contamination in food products (Government of Canada, 2010). A category 3 product is defined as food containing any of the following parameters: fresh fruits and vegetables, fermented foods, all types of sprouts, and cultured dairy products (Appendix D). Overall, addressing food safety requires a comprehensive and collaborative effort among governments, industry stakeholders, and consumers to address the challenges and maintain a safe food supply chain.

The proposed methodology is to compare the total coliform bacteria in the same potentially hazardous food (PHF) that is manufactured domestically and internationally. The goal is to determine if an external dairy market product under category three is satisfactory or comparative to a domestically manufactured one. Any knowledge obtained will aid in determining if consumers are receiving high-quality pasteurized dairy products comparable to domestically produced ones.

Literature Review:

Dairy Processing:

Dairy products contain vital nutrients such as calcium, vitamins, and proteins - these products aid in boosting health and reducing the risk of contracting diseases (Sulaiman & Hsieh, 2017). However, dairy products can foster a wide variety of microorganisms that are a common source of foodborne pathogens (Oliver et al., 2005). Their presence is due to direct contact with contamination from the farm environment or the udder of an infected animal (Oliver et al., 2005). Current regulations require milk products to undergo a pasteurization process; however, policymakers commonly overlook several factors (Oliver et al., 2005). These overlooked factors include:

- outbreaks of disease have been traced to pasteurized milk,
- unpasteurized milk is commonly consumed through several types of manufactured dairy products internationally,
- unpasteurized milk is commonly consumed by those working in the dairy processing cycle, from farmers to the staff of processing plants and onward, which creates a further risk of exposing consumers to pathogenic bacteria,
- re-contamination post-pasteurization during processing/transportation,
- the pasteurization process could be inadequate/faulty or may not destroy all foodborne pathogens in processed dairy products (Oliver et al., 2005).

Thus, these factors pose risks to the consumer via direct exposure to foodborne pathogens from imported pasteurized and unpasteurized dairy products (Oliver et al., 2005).

Due to the dietary importance of dairy, the dairy industry has undergone a copious amount of research to standardize the quality of dairy products and develop vital management practices. Studies involve testing for different micro-organism indicators to determine the quality of the finished product, sanitation, processing, and contamination post-pasteurization (Hervert et al., 2017). Also, studies in California have shown that total coliform counts in pasteurized dairy products vary significantly, as the milk sampled ranged from 31 CFU/mL (Boor et al., 1998) to 2,570 CFU/mL (Jayarao & Wang, 1999). These results have been correlated to management practices such as machine wash failures, rate of cluster washes, and milking apparatus detaching during milking (Pantoja et al., 2011). Also, research has shown that post-processing contamination is still frequent, where as many as 7% to 26% of U.S. milk samples were contaminated (Martin et al., 2012). Ultimately, recontamination of dairy products post-pasteurization is the main obstacle when striving for a high-quality dairy product (Rojas et al., 2020). In turn, the results above are staggering, as pasteurized dairy products contain psychrotolerant bacteria, meaning they can grow at refrigeration temperature levels (Martin et al., 2016). Thus, an effective surveillance program with diagnostic methods is a prerequisite to controlling or preventing foodborne illnesses in our dairy marketplace (Oliver et al., 2005). As aforementioned in the literature, our North American policies and legislations produce stringent food safety standards, but we still experience these issues with domestic products. It would be fair to assume that a greater volume of concern would arise when we expand the pool of products to include international imports. This case is especially true for instances where imported dairy goods come from regions where such policies may not be as stringent or can lack oversight in ensuring procedures are followed before and post export. Also, another problem that can arise is the conflict or disconnect between regulatory requirements between the exporting and importing locales.

Dairy-Related Hazards:

A recent study has identified that infant formula led to foodborne illness outbreaks - it contained traces of Enterobacteriaceae in the milk powder and was associated with manufacturing events. (Craven et al., 2021). Unfortunately, this case of foodborne illness affected neonates, who are underweight or immunosuppressed and thus are at greater risk (Jacobs et al., 2007). Another public health concern recently occurred in Brazil, where Shiga-toxin-producing *Escherichia coli* (STEC) was isolated from cheese, ricotta, and pasteurized cream, all ready-to-eat foods (Rosario et al., 2021). The presence of Escherichia coli is a concerning indicator as the infection rate is 100% per 2-9 CFU (Hara-Kudo & Takatori, 2011). Lastly, a recent study in Ethiopia conducted sampling on pasteurized and unpasteurized dairy products; they sampled the logistical chain including producers, collectors, processors, and retailers – it found that 86% of the samples were substandard (Mengstu et al., 2023). These metrics are concerning as international dairy products are commonly found in our marketplace in various processed forms (Douphrate et al., 2013). Additionally, milk product consumption (per capita) is significantly higher in developed countries than in developing countries (Nahar et al., 2022). If these particular products were imported into our markets, the foodborne diseases stemming from the dairy components would cause symptoms like gastrointestinal disturbance (vomiting, diarrhea) or in more severe cases, they could even be life-threatening (Mengstu et al., 2023). The CFIA's recent archives highlight that even ostensibly lower-risk dairy products, such as frozen profiteroles and eclairs, pose a significant public health hazard (Government of Canada, 2019). The mentioned unsatisfactory products containing dairy were not limited to higher-risk, potentially hazardous dairy products. Thus, imported dairy products may not always be prioritized due to resource constraints and require border resource allocation for microbiological testing.

Dairy-Related Indicators:

In general, coliforms can be categorized as facultatively anaerobic or aerobic, gram-negative, rod-shaped, non-spore-forming, and capable of fermenting lactose-producing gas and acid (Martin et al., 2016). Also, coliforms are known as indicator organisms - they represent only a fraction of the total post-pasteurization contamination. It was found that coliforms portray less than 20% of all gram-negative organisms present in fluid milk after pasteurization (Martin et al., 2018). This finding suggests that relying solely on coliform counts as an indicator of fecal contamination may not be sufficient to ensure the overall microbiological safety of pasteurized dairy products.

Other pathogenic microorganisms, such as non-coliform gram-negative bacteria and spore-forming bacteria, may also be present in milk after pasteurization (Martin et al., 2018). Therefore, additional testing and monitoring of these microorganisms may be necessary to ensure the safety and quality of dairy products. Comprehensive microbiological testing and monitoring programs can provide a more accurate assessment of the overall microbiological safety of pasteurized dairy products and reduce the risk of foodborne illness (Jayarao et al., 2004). Although standardized testing for total coliform bacteria and Enterobacteriaceae is currently in use by processors when assessing the safety of pasteurized milk as per the *Pasteurized Milk Ordinance* guidelines (Rojas et al., 2020). A study found that the primary bacteria responsible for post-processing contamination are undetected, indicating modifications to the Petro-film method can benefit dairy processors by making it possible to detect contamination from other gram-negative bacteria (Rojas et al., 2020). Currently, total coliform testing is advised by the U.S. Public Health Service - as per the *Pasteurized Milk Ordinance* (PMO) published in 1924 (Tortorello, n.d.). The current requirements for PMO limits of total coliforms found in grade A pasteurized dairy are limited to 10 or fewer CFU per mL (FDA, 1995). As coliforms are naturally present in raw milk (Jayarao & Wang, 1999), the purpose of coliform testing in a dairy product is to indicate fecal matter presence or the level of contamination of the compositional ingredients used in the preparation of the product (Martin et al., 2016). If the total coliform counts are above the *Food and Drug Administration levels of CC ≤10cfu/mL*, it signals that inadequate processing practices are in use or that post-processing contamination has occurred (Wong et al., 2010). While Total coliform testing isn't perfect, it's proven to be a fully adequate approach for evaluating the safety of imported products that are not otherwise subject to further testing under domestic policies and guidelines.

<u>Legislation and Regulations:</u>

The Canadian Food Inspection Agency (CFIA) enforces the Food and Drugs Act and associated product regulations in Canada. This organization functions on a quantitative systematic risk-based approach that categorizes and prioritizes the available inspection resources to the level of risk presented to Canadian consumers (Zanabria et al., 2019). The quantitative assessment model is designed to allocate risk to the specified commodity or product by taking into consideration the establishment and the volume of product output (Zanabria et al., 2019). An establishment is any place where a commodity/food product is produced/manufactured, processed, stored, transported, packaged, or identified (including labelling) (Zanabria et al., 2019). However, this systematic risk-based model requires historical data about risk factors at the establishment, such as compliance and inherent mitigation. This can be a drawback which would affect the conclusive risk associated with that food product/commodity– but this does direct focus on the hazards representing the highest level of food safety risk (Zanabria et al., 2019). Literature has found varying unique risk factors associated with various geographic settings across the globe, creating the need for unique policies to address the particular risk factors associated with dairy products coming from a given source locale (Butler et al., 2015; Health Canada, 2022). A particular example of this comes up when comparing the Canadian dairy industry to the United States, as raw milk is legal in some states (Butler et al., 2015) and imported products should be exposed to additional domestic regulations that are not necessarily present or accounted for in the source locale. As such, internationally manufactured products containing dairy can be difficult subjects when it comes to creating robust and standardized measures for ensuring the quality and safety of the product as a whole.

It is evident from the above literature review that a range of food safety infrastructures is in place to ensure and further increase the safety of imported foods. The continuous evolution of imported food safety regulations globally has undergone rapid developments and growth in pursuit of safer food to protect public health. This study aims to determine if a randomly selected external market dairy-containing product under market category 3 is satisfactory or comparative to a domestically manufactured one (Appendix D). The knowledge obtained will aid in identifying if consumers are receiving a high-quality pasteurized dairy product that will not expose them to adverse health effects and assess whether CFIA resource allocation is required for low-risk imported products.

Methods & Materials:

For the full list of materials used to perform the Pawkit Water Activity Meter Standard Operating Procedure and the Enumeration of Escherichia coli and coliforms in food products and food ingredients using 3M PetrifilmTM *E. coli* count plates procedure, refer to Appendix B and C.

The Standards Council of Canada has accredited *FoodAssure* with ISO 17025 since 2001, making it a reputable organization in the field of food analysis (Home: Foodassure Laboratory). As a result, the study will adopt the standardized methods and protocols recommended by *FoodAssure*, ensuring that the methods employed for total coliform analysis will be reliable.

Description of Methods:

Sample Collection:

Cheese curd snacks, or "сырки" (syroki) in Russian, are a well-known and popular snack in Eastern Europe, particularly in countries such as Russia, Ukraine, and Belarus (Ovchinnikova et al., 2018). These snacks are made from fresh cheese curds, which are typically made from cow's milk - but can also be made from goat or sheep milk (Bogdanov et al., 2017). The curds are then shaped into small, cylindrical forms and coated with a variety of toppings, including chocolate, vanilla, nuts, or fruit. The texture of “сырки” is soft and creamy, with a slightly tangy taste from the fresh cheese (Vorobeva et al., 2017). The coatings provide a sweet or savoury element to the snack, depending on the flavour. Cheese curd snacks are often consumed as a quick snack or dessert and are popular with both children and adults. In addition to being a popular snack, cheese curd snacks can also be used in other dishes, such as salads or desserts (Bogdanov et al., 2017). Their versatility and convenience make them an attractive option for many consumers who appreciate the rich and creamy flavour of fresh cheese curds.

The selection of a pasteurized dairy product that conforms to the criteria established in the literature was performed through the conduct of a preliminary water activity assessment. The objective was to ensure that the selected product had a water activity level greater than 0.85, thus classifying it as a Potentially Hazardous Food (PHF). This assessment was conducted under the guidance of faculty members at BCIT, utilizing the laboratory facilities at the institution. Prior to the initiation of the water activity test, the Pawkit water activity meter was calibrated by a laboratory technician to a specified margin of error of 0.02. The water activity assessment was performed in accordance with the standard operating procedures outlined in Appendix C, which includes information on the calibration methods and materials used.

The results of the water activity assessment indicated that cheese curd snacks had a water activity reading of 0.96 across various brands. Based on this information, cheese curd snacks were selected as the representative product for the study. This finding supports the conclusion that the chosen product meets the criteria for a PHF, as established in the literature.

A total of 60 product samples will be obtained through the systematic selection of local ethnic food stores within the lower mainland region. To ensure a random and unbiased selection process, all ethnic food stores carrying cheese curd snacks within the lower mainland will be numbered and subjected to a random selection process through the utilization of software. This methodology will eliminate any potential selection biases in the sample collection process.

The sample collection process will be performed with impartiality with respect to product branding, as the water activity tests indicated no significant variations in water activity levels across different product brands. The obtained samples will be further segregated into two categories, based on their country of origin: 30 samples will be domestically manufactured within Canada and 30 will be manufactured/distributed from international sources. The samples will be procured from refrigeration units maintained at or below 4°C to ensure that they have not undergone temperature abuse prior to purchase, as verified using a probe thermometer. The samples will be transported to the laboratory in a cooler with ice packs, and the duration of transportation should not exceed 2 hours to minimize sample handling times and to maintain the temperature of the samples at or below 4°C upon arrival at the laboratory. The enumeration of Escherichia coli and total coliforms in the samples will be conducted using 3M PetrifilmTM E. coli count plates, in accordance with standard procedures specified in classification MFHPB-34. The examination of the pasteurized dairy product samples will be performed by a third-party laboratory, which will adhere to the standardized procedures outlined in MFHPB-34 (Appendix B). The classification of various methods used to conduct microbiological analysis of food is based on Health Canada's compendium (*Government of Canada* 2022). The HPB (Harmonized Procedure for the Microbiological Analysis of Foods) Method is a standardized classification system used for the analysis of food samples. It provides a consistent approach for determining the presence of various foodborne pathogens, spoilage organisms, and indicator microorganisms (*Government of Canada* 2022).

For MFHPB-34 standardized procedures and materials conducted by the *FoodAssure Laboratory Ltd.*, refer to Appendix B.

Ethical Considerations:

This study does not involve human participants; thus, no ethical considerations are required. Furthermore, all tests conducted on the pasteurized dairy product (curd snacks) were completed through or with the aid of a third party, removing ethical bias. However, if high levels of total coliforms are found that are above the satisfactory limits specified by *Microbial Guidelines for Ready-to-Eat Foods – A Guide for the Conveyance Industry and Environmental Health Officers (EHO)*, results will be forwarded to the regulating body by the laboratory (Appendix D).

Statistical Analysis:
Description of Data & Analysis:

The populations of *E. coli* and total coliforms will be calculated after obtaining results from the petrifilm plate counts provided by *FoodAssure Laboratory* (Appendix A). The data obtained is discrete and numerical, meaning that measurements will be limited to whole numbers. Furthermore, it is implausible to imply that half of a total coliform exists; hence, data is discrete and not continuous. All obtained data will be grouped and represented in tables in Appendix A.

Inferential Statistics:

The *Two-Sample T-test* has been selected as the statistical test for this study, in accordance with the findings from the literature review. This statistical test is appropriate for comparing the means of two independent sample groups, specifically, domestically manufactured dairy products and internationally manufactured dairy products. In addition to the *Two Sample T-test*, a box plot may be utilized to visually depict potential differences in the means of the two sample groups. Furthermore, the discrete statistics that will be analyzed include the mean, median, range, and standard deviation, which will provide a comprehensive understanding of the distribution of the data. In conclusion, the choice of the *Two-Sample T-test*, combined with the visual representation of the data through a box plot, and the analysis of discrete statistics, will provide robust and reliable results that will allow for a thorough examination of the differences between the means of domestically manufactured and internationally manufactured dairy products.

The statistical package used was *NCSS* 2023. Both the descriptive and complex inferential statistics will use *NCSS 2023* to determine the significance of our study

Hypothesis:

H_0:	There is no difference in the mean total coliform levels in pasteurized imported dairy cheese curd snacks compared to the mean coliform levels in domestic pasteurized dairy cheese curd snacks.
H_a:	There is a difference between the mean total coliform levels in pasteurized imported dairy cheese curd snacks compared to the mean coliform levels in domestic pasteurized dairy cheese curd snacks.

Table 1: **H_0 & H_a for Two-Tailed 2 Sample T-test**

Interpretation of Results:

The data and completed statistical analysis are found in Appendix A. Each independent group was composed of 30 observations. The mean of total coliform in domestic curd snacks was less than 10 CFU/g, similarly, the imported curd snacks were also less than 10 CFU/g. These identical results imply that international cheese curd snacks are equivalent to domestically produced cheese curd snacks, as they both have the same mean value of zero. It should be noted that the results for both domestically and internationally produced-cheese curd snacks showed no detectable differences in their samples. However, it is important to keep in mind that the statistical method used could not determine if there was any variability between the two datasets, meaning that hypothesis testing; and the probabilities of alpha and beta errors may not be relevant. Nevertheless, in certain situations, it may be acceptable to assume that the two datasets are identical. Overall, a value of zero for both datasets indicates that there is no difference between the means of the two groups being compared. In this case, the p-value would be 1, indicating that there is a high probability that any observed differences between the means are due to chance alone. However, Power =1-β, but in this scenario, the power of the test is undefined because there is no variation in the data to detect any true differences or effects. Furthermore, Type 1 and Type 2 errors are not relevant in this scenario, as there are no differences between incorrect detection or the failure of detecting them. Hence, this study was not able to find sufficient evidence and accepts the H_0; there is no difference in the mean total coliform levels in pasteurized imported dairy cheese curd snacks compared to the mean coliform levels in domestic pasteurized dairy cheese curd snacks, as results show that both dairy products have 0 CFU/g counts.

Refer to Appendix A for the trial run, data tables, and statistical analysis using Microsoft Excel and NCSS.

Discussion:

The study aimed to compare the levels of total coliforms in domestic and international curd snacks and determine if the difference in levels was due to the origin of the ingredients used. The results showed that there was no significant difference in the levels of total coliforms between the two categories, with both types of curd snacks having results below the detectable limits of the methods used. These findings indicate that both domestic and international curd snacks are safe for consumption in Canada, despite differences in regulations and production methods used in different countries. Our study results are consistent with previous research that has found low levels of total coliforms in dairy products (Krishna et al., 2021). However, our study's findings challenge the premise put forth in the literature review that regulatory systems are the sole determinant of food product safety. Instead, the results suggest that effective safety measures can be implemented irrespective of the regulatory framework that support the importance of regulations and health professionals in ensuring the safety and quality of food products (Government of Canada, 2020).

The results of our study were consistent with previous research that found low levels of total coliforms in dairy products (Krishna et al., 2021). However, our study differed in that it aimed to compare the levels of total coliforms in domestic and international curd snacks, whereas previous research may have focused on other types of dairy products. Furthermore, the primary findings of our study, which reported low levels of total coliforms in domestic and international curd snacks, are in agreement with previous research that has highlighted the importance of intrinsic and extrinsic factors in influencing microbial growth in food (Hamad, 2012). Specifically, factors such as nutrient content, water activity, pH value, temperature, and storage conditions have been shown to play a critical role in promoting or inhibiting the growth of microorganisms in food. In other words, given that the quality of the end product may be affected by the sampling process and that the low levels of total coliforms observed in our study may be attributed to the handling steps after the critical control points, it can be inferred from our findings that the pH value, temperature, and storage conditions of the curd snacks may have contributed to the observed low levels of total coliforms. Thus, our study's results suggest that there is a comparable quality and safety of pasteurized dairy products manufactured domestically, regardless of the region, to those produced internationally in the same category. This finding not only verifies prior domestic research but also provides evidence that the quality and safety of domestically produced dairy products can match up to imported ones. By focusing on imports, our study highlights the importance of maintaining stringent regulatory standards to ensure that consumers receive high-quality pasteurized dairy products, irrespective of where they are manufactured.

Limitations:

While the findings of our study provide valuable insights into the microbiological quality of curd snacks in the lower mainland of British Columbia, it is important to note that our sample was limited to this geographical area. As such, our results may not be generalizable to other regions of the country or province. This limitation is particularly relevant for domestic products, which are likely to have regional differences due to variations in the manufacturing process and sourcing of raw materials. However, for the international product, which is widely distributed, this limitation may be less significant. Nonetheless, caution should be exercised when interpreting and applying our findings to other regions or contexts beyond the scope of our study. Additionally, the study only focused on one type of food product, and further research may be needed to generalize the findings to other types of dairy products. However, the study used a standardized analysis method (MFHPB-34), which is a dependable and widely used method for detecting total coliforms in food products (Appendix A). Further research may be needed to generalize the findings to other types of dairy products and other populations outside of Canada. Additionally, the following limitations must be considered when interpreting the results. One of the main limitations is the cost of laboratory testing. As a result, we were unable to evaluate a larger sample size. The limited sample size, as noted earlier, was due to current market availability, which restricted our ability to collect more samples for analysis. However, it is important to note that when a sample size is small, as in our case, there is a higher likelihood of chance variation or sampling error, which can lead to results that are not representative of the sample selection being studied. Therefore, the small sample size may have introduced a level of uncertainty to our study's findings. Despite these hindrances, we believe that the use of standardized microbiological testing methods increased the reliability and validity of the results, and this, in turn, made the sample size sufficient in representing the curd snacks available in the Canadian market. Furthermore, another limitation of this study is the potentially inaccurate representation of contamination levels in products with quantifiable data below the threshold of ten coliforms. This is due to the method used in the study, MFHPB-34, which has a detection limit of ten coliforms per sample. Any count below this threshold is considered negative, and the actual count of coliforms present in the sample cannot be determined. It is possible that some samples contained a low level of coliforms that were not detected by the method used in the study. However, since the results were below the detectable range, quantifying total coliform levels below ten colony-forming units (cfu) was not considered important from a food safety perspective. Finally, the study only focused on one type of dairy product available in the Canadian marketplace (curd snack), which limits the generalizability of the findings to other types of dairy products. Further research is needed to determine if comparable results would be obtained for the other types of category three dairy products. While this study provides valuable insights into the levels of total coliforms in domestic and international curd snacks, it is important to consider the limitations outlined above when interpreting the results. While the study suggests that both domestic and international curd snacks are safe for consumption, it does not provide information about the adequacy or effectiveness of international regulatory systems.

Knowledge Translation and Recommendations:

To enhance food safety in the Canadian dairy market, we recommend manufacturers and distributors implement rigorous quality control measures, including regular testing for harmful microorganisms such as coliforms. Proper handling and hygiene practices should also be enforced throughout the production, distribution, and retail processes to minimize the risk of contamination. Additionally, processing methods and storage conditions should be optimized to prevent the growth and spread of coliforms. Moreover, we suggest that consumers be educated on the safe handling and storage of dairy products through public awareness campaigns, educational materials, and labelling initiatives. Furthermore, regulatory agencies should establish and enforce stringent food safety standards and regulations to ensure the safety and quality of dairy products in the Canadian market. These measures will help mitigate the risks associated with coliform contamination, enhancing food safety, and reducing public health hazards.

Future Research:

Future student projects based on this study could include:

- Future student projects based on this study could include:
- Investigating the prevalence of other contaminants in curd snacks and dairy products using more sensitive detection methods such as polymerase chain reaction (PCR) or next-generation sequencing (NGS).
- Conducting a larger-scale study to determine if comparable results would be obtained for other types of curd snacks or dairy products.
- Comparing the safety of curd snacks and other dairy products from different regions or countries to determine if there are any significant differences in contamination levels.

Conclusion:

In conclusion, this research's results indicate no statistically significant difference in the levels of total coliforms between the domestic and international curd snack samples available in the Canadian market. Moreover, none of the analyzed samples exceeded the regulatory limit for total coliforms in category 3 dairy products established by the Canadian government. These findings suggest that both domestic and international curd snacks available in the Canadian market are safe for consumption and meet the regulatory requirements for total coliforms. The results could have practical significance for food safety regulations and industry practices in Canada and other countries where curd snacks and similar dairy products are popular.

Acknowledgements:

The successful completion of this research study was made possible with the guidance and supervision of Dale Chen, who provided valuable insights and support throughout the process. The author would like to express sincere gratitude to Dale Chen for his contribution. The author also wishes to extend thanks to *FoodAssure Laboratory Ltd*. for their collaboration and assistance in obtaining this study's primary data and resources. Their expertise and support were instrumental in the successful completion of this project. Finally, the author would like to thank all participants who took part in this study, without whom this research would not have been possible. Their willingness to participate and provide valuable insights has been greatly appreciated.

Competing Interest:

The authors wish to disclose that while they have no competing interests that could influence the objectivity of this research, it is important to note that additional resources were required to carry out the laboratory testing in an accredited facility. This investment and involvement in the research topic were necessary to ensure the quality and reliability of the results obtained in this study. However, these resources were not provided by any external organization or entity that may have a stake or interest in the findings of this research, and thus, the author asserts that there are no competing interests that may affect the impartiality and integrity of the study.

References:

Aerobic Colony Count (ACC) – Food. (n.d.). Public Health Ontario. Retrieved November 22, 2022, from https://www.publichealthontario.ca/en/laboratory-services/test-information-index/heterotrophic-plate-count-food#:~:text=ACC%20cannot%20be%20applied%20to

Bogdanov, I., Lopatin, S., Petrov, V., & Melnikova, I. (2017). T*he technology of producing cheese snacks of a new generation*. Foods and Raw Materials, 5(1), 125-132.

Boor, K. J., Brown, D. P., Murphy, S. C., Kozlowski, S. M., & Bandler, D. K. (1998). Microbiological and Chemical Quality of Raw Milk in New York State. *Journal of Dairy Science*, *81*(6), 1743–1748. https://doi.org/10.3168/jds.S0022-0302(98)75742-X

Butler, A. J., Thomas, M. K., & Pintar, K. D. M. (2015). Expert elicitation as a means to attribute 28 enteric pathogens to foodborne, waterborne, animal contact, and person-to-person transmission routes in Canada. *Foodborne Pathogens and Disease*, *12*(4), 335–344. https://doi.org/10.1089/fpd.2014.1856

Buzby, J. C. (2003). *International Trade and Food Safety: Economic Theory and Case Studies*. www.ers.usda.gov

Canada, H. (2022, October 4). *Government of Canada*. Canada.ca. Retrieved February 9, 2023, from https://www.canada.ca/en/health-canada/services/food-nutrition/research-programs-analytical-methods/analytical-methods/compendium-methods/methods-microbiological-analysis-foods-compendium-analytical-methods.html

Centers for Disease Control and Prevention. (2021). *Food Safety*. Retrieved from https://www.cdc.gov/foodsafety/index.html

Craven, H., McAuley, C., Hannah, M., Duffy, L., Fegan, N., & Forsythe, S. (2021). Applicability of Enterobacteriaceae and coliforms tests as indicators for Cronobacter in milk powder factory environments. *Food Microbiology*, *94*. https://doi.org/10.1016/j.fm.2020.103642

C.R.C., c. 870. (2022). *Food and Drug Regulations*. http://laws-lois.justice.gc.ca/eng/regulations/C.R.C.%2C_c._870/

Douphrate, D. I., Hagevoort, G. R., Nonnenmann, M. W., Lunner Kolstrup, C., Reynolds, S. J., Jakob, M., & Kinsel, M. (2013). The Dairy Industry: A Brief Description of Production Practices, Trends, and Farm Characteristics Around the World. *Journal of Agromedicine*, *18*(3), 187–197. https://doi.org/10.1080/1059924X.2013.796901

FDA. (1995). Standards for grade "A" milk and milk products," in Grade "A" Pasteurized Milk Ordinance. *Washington, DC: U.S. Department of Health and Human Services, Public Health Service*, 28–31.

Government of Canada, C. F. I. A. (2020, January 24). *Certain milk products may be unsafe due to the presence of sanitizer*. Inspection.canada.ca. https://inspection.canada.ca/food-recall-warnings-and-allergy-alerts/2020-01-24/eng/1579917929687/1579917934748

Government of Canada, P. S., and P. C. (2010). Microbial Guidelines for Ready-to-Eat Foods – A Guide for the Conveyance Industry and Environmental Health Officers (EHO). Publications.gc.ca. https://publications.gc.ca/collections/collection_2014/sc-hc/H164-167-2013-eng.pdf

Hamad, S. H. (2012). Factors affecting the growth of microorganisms in food. *Progress in Food Preservation*, 405–427. https://doi.org/10.1002/9781119962045.ch20

Hara-Kudo, Y., & Takatori, K. (2011). Contamination level and ingestion dose of foodborne pathogens associated with infections. *Epidemiology and Infection*, *139*(10), 1505–1510. https://doi.org/10.1017/S095026881000292X

Hervert, C. J., Martin, N. H., Boor, K. J., & Wiedmann, M. (2017). Survival and detection of coliforms, Enterobacteriaceae, and gram-negative bacteria in Greek yogurt. *Journal of Dairy Science*, *100*(2), 950–960. https://doi.org/10.3168/jds.2016-11553

Home: Foodassure Laboratory. foodassure. (n.d.). Retrieved February 9, 2023, from https://www.foodassure.com/

Jayarao, B. M., Donaldson, S. C., Straley, B. A., Sawant, A. A., Hegde, N. V., Brown, J. L., & Bolin, C. A. (2004). A survey of foodborne pathogens in bulk tank milk and raw milk consumption among farm families in Pennsylvania. *Journal of Dairy Science*, 87(6), 1641-1649.

Jayarao, B. M., & Wang, L. (1999). A study on the prevalence of gram-negative bacteria in bulk tank milk. *Journal of Dairy Science*, *82*(12), 2620–2624. https://doi.org/10.3168/jds.S0022-0302(99)75518-9

Krishna, T. C., Najda, A., Bains, A., Tosif, M. M., Papliński, R., Kapłan, M., & Chawla, P. (2021). Influence of Ultra-Heat Treatment on Properties of Milk Proteins. *Polymers*, *13*(18), 3164. https://doi.org/10.3390/polym13183164

Magd, H., & Nabulsi, F. (2012). The Effectiveness of ISO 9000 in an Emerging Market as a Business Process Management Tool: The Case of the UAE. *Procedia Economics and Finance*, *3*, 158–165. https://doi.org/10.1016/S2212-5671(12)00135-9

Martin, N. H., Boor, K. J., & Wiedmann, M. (2018). Symposium review: Effect of post-pasteurization contamination on fluid milk quality. *Journal of Dairy Science*, *101*(1), 861–870. https://doi.org/10.3168/jds.2017-13339

Martin, N. H., Carey, N. R., Murphy, S. C., Wiedmann, M., & Boor, K. J. (2012). A decade of improvement: New York State fluid milk quality. *Journal of Dairy Science*, *95*(12), 7384–7390. https://doi.org/10.3168/jds.2012-5767

Martin, N. H., Trmcic, A., Hsieh, T. H., Boor, K. J., & Wiedmann, M. (2016). The evolving role of coliforms as indicators of unhygienic processing conditions in dairy foods. In *Frontiers in Microbiology* (Vol. 7, Issue SEP). Frontiers Research Foundation. https://doi.org/10.3389/fmicb.2016.01549

Mengstu, B., Tola, A., Nahusenay, H., Sisay, T., Kovac, J., Vipham, J., & Zewdu, A. (2023). Evaluation of microbial hygiene indicators in raw milk, pasteurized milk and cottage cheese collected across the dairy value chain in Ethiopia. *International Dairy Journal*, *136*. https://doi.org/10.1016/j.idairyj.2022.105487

Nahar, A., Mila, F. A., Culas, R. J., & Amin, M. R. (2022). Assessing the factors and constraints for value chain development of dairy food products in

Bangladesh. *Heliyon*, *8*(10), e10787. https://doi.org/10.1016/j.heliyon.2022.e10787

Oliver, S. P., Jayarao, B. M., & Almeida, R. A. (2005). Review Foodborne Pathogens in Milk and the Dairy Farm Environment: Food Safety and Public Health Implications. In *FOODBORNE PATHOGENS AND DISEASE* (Vol. 2, Issue 2). www.liebertpub.com

Ovchinnikova, S., Gorlova, O., Gudkova, I., Ryskova, E., & Sidorov, I. (2018). *Development of the technology of cheese snacks with different fillings*. Foods and Raw Materials, 6(1), 102-110.

Pantoja, J. C. F., Reinemann, D. J., & Ruegg, P. L. (2011). Factors associated with coliform count in unpasteurized bulk milk. *Journal of Dairy Science*, *94*(6), 2680–2691. https://doi.org/10.3168/jds.2010-3721

Rahmat, S., Cheong, C. B., & Hamid, M. S. R. B. A. (2016). Challenges of Developing Countries in Complying Quality and Enhancing Standards in Food Industries. *Procedia - Social and Behavioral Sciences*, *224*, 445–451. https://doi.org/10.1016/J.SBSPRO.2016.05.418

Rojas, A., Murphy, S. I., Wiedmann, M., & Martin, N. H. (2020). Short communication: Coliform Petrifilm as an alternative method for detecting total gram-negative bacteria in fluid milk. *Journal of Dairy Science*, *103*(6), 5043–5046. https://doi.org/10.3168/jds.2019-17792

Rosario, A. I. L. S., Castro, V. S., Santos, L. F., Lisboa, R. C., Vallim, D. C., Silva, M. C. A., Figueiredo, E. E. S., Conte-Junior, C. A., & Costa, M. P. (2021). Shiga toxin–producing Escherichia coli isolated from pasteurized dairy products from Bahia, Brazil. *Journal of Dairy Science*, *104*(6), 6535–6547. https://doi.org/10.3168/jds.2020-19511

Sulaiman, I. M., & Hsieh, Y. H. (2017). Foodborne Pathogens in Milk and Dairy Products: Genetic Characterization and Rapid Diagnostic Approach for Food Safety of Public Health Importance. *Diary in Human Health and Disease across the Lifespan*, 127–143. https://doi.org/10.1016/B978-0-12-809868-4.00009-1

Tchou-San-Da N., J., Chen, D., Piesik, C. (2023). Public Health Risks and External Food Safety in the Canadian Marketplace. BCIT, Environmental Health Journal.

Terziovski, M., & Guerrero, J. L. (2014). ISO 9000 quality system certification and its impact on product and process innovation performance. *International Journal of Production Economics*, *158*, 197–207. https://doi.org/10.1016/J.IJPE.2014.08.011

Tortorello, M. L. (n.d.). *Indicator Organisms for Safety and Quality-Uses and Methods for Detection: Minireview*. https://academic.oup.com/jaoac/article/86/6/1208/5657037

Vorobeva, N., Koryukina, M., & Kuzmenko, E. (2017). *Production of cheese snacks with a high content of protein.* Foods and Raw Materials, 5(2), 120-127.

Wong, T., Haynes, N., & Eddy, D. (2010). Using indicator organisms for quality and safety in dairy manufacturing. *Australian Journal of Dairy Technology*, *65*(2), 113–117.

Zanabria, R., Racicot, M., Leroux, A., Xucen, L., Cormier, M., Ferrouillet, C., Arsenault, J., Mackay, A., Griffiths, M., Holley, R., Gill, T., Charlebois, S., Farber, J., Fazil, A., & Quessy, S. (2019). Source attribution at the food sub-product level for the development of the Canadian Food Inspection Agency risk assessment model. *International Journal of Food Microbiology*, *305*. https://doi.org/10.1016/j.ijfoodmicro.2019.108241