Ontario

Cabbage

5.0 Cabbage Food Safety Risk Assessment

Food Inspection Branch
Food Industry Division
Ontario Ministry of Agriculture and Food

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Pre-Production ***Site Selection and Preparation*** This includes application of soil amendments such as manure, biosolids, chemical fertilizers etc. prior to planting.	**Biological** Concern that pathogens existing in soil, water and applied amendments may contaminate the future cabbage crop (2, and 7). A foodborne outbreak of *Listeria monocytogenes* found in coleslaw was traced back to a cabbage field fertilized with sheep manure (101). See Appendix B for a list of pathogens known to contaminate produce.	Nglg-Low Although the possibility of contamination exists, microbial and environmental degradation of pathogens over time reduces the likelihood of contaminating the crop (15). One study indicates that in the presence of pathogens there is some potential for infiltration, survival, and growth of pathogens in vegetables (7). There is some opportunity for contamination where animal agriculture is in close proximity, and where water could flow from these farms to cabbage fields or into water sources used for cabbage production.	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is extremely low as most pathogens are found on outer cabbage leaves, which are normally removed during trimming, harvest, packing, and prior to consumption (15). Pathogens are also reduced by microbial and environmental degradation during the growing season.	Low Some foodborne pathogens are easily transmitted directly by person-to-person, or by the fecal oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly and immune-compromised are at greater risk (21, and 40). Symptoms may vary from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 25, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility, and size of outbreak (2). If an outbreak is traceable to a specific company or industry, the economic impact for that company could be significant (26, 27, 28, and 69).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med One outbreak of *Listeria* was traced back to the production of cabbage in Nova Scotia, where *Listeria*-infected sheep manure was used as fertilizer. Additional data are limited. Knowledge of plant growth, the agricultural industry, and limited traceable cases provide reasonable certainty of the assessment.	**Nglg-Low** The probability of contamination is mainly negligible, and exposure from contamination at this stage of production is unlikely. The impacts of contamination are mostly low. While there is some uncertainty, the overall risk is considered negligible.	**To reduce risk:** Use Good Agricultural Practices (GAPs) (30). Investigate previous uses and history of the site and adjacent sites. Test soil amendments for pathogens where any potential concern exists. Manure should be applied and incorporated into the soil the previous fall, if possible. Only apply well-composted manure to the soil. Apply biosolids and sewage biosolids at least 12 months prior to planting. This requires a permit and the Ministry of Environment (MOE) approval.

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Pre-Production ***Site Selection and Preparation*** This includes application of soil amendments such as manure, biosolids, chemical fertilizers etc. prior to planting.	**Chemical** Concern that intentionally applied products or chemicals from the environment, at or near the production site, will contaminate the future cabbage crop (40).	Nglg-Low Agricultural chemicals registered for use are routinely applied to the soil at this stage. However, the cabbage crop is not yet present to become contaminated. The probability of chemicals being present at levels higher than is allowed at the time of consumption is quite low, due to processes in place to control registration, selling, storage, and use of chemicals on food (40, and 78).	Nglg-Low Produce is not identified as a main source of exposure to chemicals and metals (35). Although possible, the probability of consumer exposure to chemicals from this stage of production is quite low (39, 40, and 44). Chemicals may dissipate, degrade or be eliminated over time, and through trimming and removal of leaves during harvest, and prior to packing.	Nglg Chemicals are not conducive to secondary spread among humans.

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Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traced back to a specific company or industry, the indirect economic impact may be significant (43).	Nglg At the levels at which chemicals are found in food, the impact of contaminated food on the environment would be negligible.	Low-Med While there are no specific data on the uptake or impact of environmental chemicals found in cabbage, studies have indicated that toxic chemicals can accumulate in produce. Results from the Ontario Food Safety Monitoring Program indicate a very low incidence of chemical residues exceeding the allowable Maximum Residue Limits (MRLs) as set by Health Canada (45, and 46).	**Nglg** Although impact could potentially be medium, and specific data are limited, it is reasonably certain that the overall risk at this stage of production is negligible, due to the very low probability of consumer exposure.	**To reduce risk:** Investigate previous uses of the site and adjacent sites. Apply biosolids and sewage biosolids a minimum of 12 months prior to planting. This requires a permit and the Ministry of Environment (MOE) approval. Test soil for chemicals where the possibility of contamination exists. Follow label requirements on all chemicals applied to the cabbage crop. Do not use chemicals not registered for use on cabbage. Follow guidelines for use of biosolids as set out in OMAF fact sheet #95-069. Follow cabbage seed handling and production recommendations as set out in OMAF publication #363.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
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Pre-Production ***Site Selection and Preparation*** This includes application of soil amendments such as manure, biosolids, chemical fertilizers etc. prior to planting.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate the future cabbage crop. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is unlikely to incorporate extraneous material into its structure. The probability of any physical extraneous material contaminating cabbage at the pre production stage is negligible.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled prior to consumption, which should remove extraneous material on or near the surface.	Nglg Physical hazards are not conducive to secondary spread.

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Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traced back to a specific company or industry, the economic impact would be low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Nglg-Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage plant growth and production, provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at pre production is negligible.	**To reduce risk:** Follow Good Agricultural Practices (GAPs) (30). Keep fields free of debris.

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Production ***Growing the Crop*** Application of fertilizer, crop protection materials and other soil or crop amendments.	**Biological** Concern that pathogens such as *Listeria*, *E. coli 0157:H7*, *Cryptosporidium*, *Salmonella*, and Hepatitis A, could contaminate the cabbage from water used for irrigation and spray application, worker hygiene while working in the field, and bird and animal sources. See Appendix B for a list of foodborne pathogens known to contaminate produce.	Nglg-Med If contaminated water or other products are applied, contamination may occur. *E.coli* and *Cryptosporidium* are often found in surface water in Ontario (12). *E. coli*, *Salmonella*, and *Campylobacter* may be present in manure and can live in soil for up to three months (11). One study indicates that in the presence of pathogens, there is some potential for infiltration, survival and growth of pathogens in vegetables (7).	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is very low as most pathogens are usually found on outer cabbage leaves, which are normally removed during trimming, harvest, packing, and again, prior to consumption (69). Microbial and environmental degradation of pathogens over time reduce the likelihood of exposure.	Low Some foodborne pathogens are easily transmitted directly by person-to-person, or by the fecal to oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

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Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly and immune-compromised are at greater risk (40). Symptoms are variable, from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 78, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility and size of outbreak (2). If an outbreak is traced back to a specific company or industry, the indirect economic impact could be high (68, and 102).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med One outbreak of *Listeria* was traced back to the production of cabbage in Nova Scotia, where *Listeria*-infected sheep manure was used as fertilizer (101). Additional data are limited. Knowledge of plant growth, the agricultural industry, and limited traceable cases provide reasonable certainty of the assessment.	**Nglg-Low** The probabilities of contamination and exposure at this stage of production are quite low, and the impacts of contamination are mainly low. While there is some uncertainty, the overall risk is expected to be negligible to low.	**To reduce risk:** Use Good Agricultural Practices (GAPs) (30). Use potable water where possible. Have proper toilet and hand washing facilities in the field for workers. Irrigation water should be tested regularly for coliforms. Manure should be applied and incorporated into the soil the previous fall, if possible. Only apply well-composted manure to the soil. Apply biosolids and sewage biosolids at least 12 months prior to planting. This requires a permit and the Ministry of Environment (MOE) approval.

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Production ***Growing the Crop*** Application of fertilizer, crop protection materials and other soil or crop amendments.	**Chemical** Contamination of cabbage with applied products such as fertilizer, herbicides, fungicides and other soil or crop amendments, prior to planting the crop. While the level of chemicals in food is usually quite low, it has been suggested that foods are a potential source of exposure to chemicals (35, and 36).	Med-High Agricultural chemicals registered for use are routinely applied at this stage (158). Plants absorb chemicals from the environment during growth (37). The probability of chemicals being present at levels higher than is allowed at the time of consumption is quite low, due to processes in place to control registration, selling, storage, and use of chemicals on food (40, and 78). If labels are followed, the probability of contaminating the crop at this stage is considered medium to high (46).	Low Produce is not identified as a main source of exposure to chemicals and metals (35). Although possible, the probability of consumer exposure to chemicals from this stage of production is quite low (39, 40, and 44). Chemicals may dissipate, degrade or be eliminated over time, and through trimming and removal of leaves during harvest, and prior to packing.	Nglg Chemicals are not conducive to secondary spread among humans.

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Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traced back to a specific company or industry, the indirect economic impact may be significant (43).	Nglg-Low At the levels at which chemicals are found in food, the impact of contaminated food on the environment would be negligible.	Low Results from the Ontario Food Safety Monitoring Program indicate a very low incidence of chemical residues exceeding the allowable Maximum Residue Limits (MRLs) as set by Health Canada (45, and 46). The lack of traceable cases provides reasonable certainty of the assessment.	**Nglg-Low** Although the impact could be medium and data for specific long-term effects are limited, the overall risk of illness from registered pesticides is negligible to low, due to the low probability of consumer exposure.	**To reduce risk:** Use Good Agricultural Practices(GAPs) (30). Follow label requirements on all chemicals applied to the cabbage crop. Do not use chemicals that are not registered for use on cabbage. Follow guidelines for use of biosolids as set out in OMAF fact sheet #95-069. Follow cabbage production and seed handling recommendations as set out in OMAF publication #363.

Activity	Hazard/ Concern	Risk Characterization		
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Production ***Growing the Crop*** Application of fertilizer, crop protection materials and other soil or crop amendments.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate the future cabbage crop. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is unlikely to incorporate extraneous material into its structure. The probability of any physical extraneous material contaminating cabbage during crop production is very low.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled prior to consumption, which should remove extraneous material on or near the surface.	Nglg The nature of the physical hazard is not conducive to secondary spread.

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Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traceable to a specific company or industry, the economic impact would be low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage plant growth and production provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at production is negligible.	**To reduce risk:** Follow Good Agricultural Practices (GAPs) (30). Keep fields free of debris.

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Production ***Harvesting*** Hand harvesting of cabbage and either packing directly into market containers or loading into larger containers for storage.	**Biological** Concern that cabbage could become contaminated during harvest from workers, containers, or soil. Containers and harvesting equipment may be exposed to soil, bird, and animal feces. Two foodborne outbreaks of *E. coli* in coleslaw are traceable to restaurants where workers did not wash their hands properly, prior to making coleslaw (102).	Low Although unlikely, contamination of produce at harvest may occur. Workers have contact with each head of cabbage at harvest. Contamination of plant tissue is largely associated with the outer surface. Inner tissue of sound produce is considered sterile (15).	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is very low, as most pathogens are usually found on outer cabbage leaves, which are normally removed during trimming, harvest, packing, and prior to consumption (69). Pathogens are also reduced by microbial and environmental degradation during the growing season.	Low Some foodborne pathogens are easily transmitted directly by person-to-person, or by the fecal to oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

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Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly and immune-compromised are at greater risk (21, and 40). Symptoms are variable, from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 25, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility and size of outbreak (2). If an outbreak is traced back to a specific company or industry, the economic impact could be significant for that company (26, 27, 28, 68, and 102).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med Although two outbreaks of *E. coli* in coleslaw were not directly related to harvest, they were traceable to restaurant workers who did not wash their hands properly, prior to cutting the cabbage (102). Additional data are limited. Knowledge of plant growth, the agricultural industry, and limited traceable cases, provide reasonable certainty of the assessment.	**Low** The probabilities of contamination and exposure at this stage of production are quite low, and the impacts of contamination are mostly low. While there is some uncertainty, the overall risk is expected to be low.	**To reduce risk:** Have proper toilet and hand washing facilities available to workers in the field. Ensure that harvesting equipment and all containers are clean and free from animal and bird feces.

Activity	Hazard/ Concern	Risk Characterization		
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Production	**Chemical**	Nglg	Nglg	Nglg
Harvesting Hand harvesting of cabbage and either packing directly into market containers or loading into larger containers for storage.	Concern that cabbage may become contaminated with chemicals during harvest. While the level of chemicals in food is usually quite low, it has been suggested that foods are a potential source of exposure to chemicals (35, and 36).	No chemicals are deliberately applied during the harvest process. The only potential contamination at this stage of production is from agricultural fluids used in equipment, and chemically contaminated containers. The probability of chemical contamination of cabbage at this stage is considered negligible.	Produce is not identified as a main source of exposure to chemicals and metals (35). Although possible, the probability of consumer exposure to chemicals from this stage of production is quite low (39, 40, and 44). Chemicals may dissipate, degrade or be eliminated through trimming and removal of leaves during harvest, and prior to packing.	Chemicals are not conducive to secondary spread among humans.

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Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traceable to a specific company or industry, the indirect economic impact may be significant (43).	Nglg At the levels at which chemicals are found in food, the impact of contaminated food on the environment would be negligible.	Low Results from the Ontario Food Safety Monitoring Program indicate a very low incidence of chemical residues exceeding the allowable Maximum Residue Limits (MRLs) as set by Health Canada (45, and 46). The lack of traceable cases provides reasonable certainty of the assessment.	**Nglg** Although impact could be medium and data for specific long-term effects are limited, the overall risk of illness from chemicals is negligible to low, due to the negligible probability of contamination and human exposure.	**To reduce risk:** Use Good Agricultural Practices (GAPs) (30). Ensure containers have not been used for storing chemicals. Investigate the source of the containers and what materials were used to manufacture the containers. Ensure that all machinery is well maintained and that lubricants are not leaking.

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Production ***Harvesting*** Hand harvesting of cabbage and either packing directly into market containers or loading into larger containers for storage.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate cabbage. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is not likely to incorporate extraneous material into its structure. The probability of any physical extraneous material contaminating cabbage at the harvesting stage is negligible.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled, prior to consumption, which should remove extraneous material on or near the surface.	Nglg The nature of the physical hazard is not conducive to secondary spread.

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Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traceable to a specific company or industry, the economic impact would be low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage plant growth and production provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at the harvesting stage is negligible.	**To reduce risk:** Use Good Agricultural Practices (GAPs) (30). Only use sound containers for harvesting and packing cabbage. Provide information to employees on potential physical hazards. If cabbage is contaminated with dirt, trim back to clean heads.

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Post Harvest ***Storage*** Containers of cabbage are stored in refrigerated or unrefrigerated facilities. Cabbages may be stored for up to seven months.	**Biological** Pathogens absorbed by cabbage from rodent and animal droppings. Higher temperature storage allows pathogens to multiply. Concern that cabbage could become contaminated during storage through contact with contaminated storage areas, climate control equipment, water or pests.	Nglg-Low Foodborne pathogens can be transmitted in storage through feces. There is some potential for pests to have contact with cabbage in storage (15). If cabbage is not stored at proper temperatures, existing pathogens may grow and increase the level of contamination. Cabbages in boxes or bins are not likely to be contaminated by storage surfaces.	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is very low, as most pathogens are usually found on the outer cabbage leaves, which are normally removed during trimming, at harvest and packing, and prior to consumption (69). While most pathogens do not grow well at low temperatures, *Listeria* is able to grow in storage temperatures (57).	Low Some foodborne pathogens are easily transmitted directly by person-to-person, or by the fecal to oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

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Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly, and immune-compromised are at greater risk (21, and 40). Symptoms are variable, from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 25, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility and size of outbreak (2). If an outbreak is traceable to a specific company or industry, the economic impact could be significant for that company (26, 27, 28, 68, and 102).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med No previous biological hazards attributed to cabbage during this stage are identified. Experience, knowledge of plant growth and the industry, and lack of traceable cases provide reasonable certainty of the assessment.	**Nglg-Low** The probabilities of contamination and exposure are very low. The impact of contamination is mostly low. While there is some uncertainty, the overall risk is expected to be quite low.	**To reduce risk:** Use Good Agricultural Practices (GAPs) (30). Ensure storage is free of animals and rodents. Bait stations should be monitored and maintained. Wash and sanitize storage room before cabbages are brought into the room. Follow temperature recommendations as set out in the Vegetable Production Recommendations Publication #363. Monitor and clean climate control equipment. Prevent condensation water from dripping onto cabbage.

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Post Harvest ***Storage*** Containers of cabbage are stored in refrigerated or unrefrigerated facilities. Cabbages may be stored for up to seven months.	**Chemical** Chemical contamination from climate control equipment (leaks in the system). Contamination from cleaners, disinfectants, and sanitizers. Agricultural chemicals stored near the storage room. While the level of chemicals in food is usually quite low, it has been suggested that foods are a potential source of exposure to chemicals (35, and 36).	Nglg No chemicals are deliberately applied during storage. Chemicals from cooling equipment may cause contamination, but the likelihood of this occurring is extremely low. The probability of chemical contamination at this stage is considered negligible.	Nglg-Low Produce is not identified as a main source of exposure to chemicals and metals (35). Although possible, the probability of consumer exposure to chemicals from this stage of production is quite low (39, 40, and 44). Chemicals may dissipate, degrade or be eliminated through trimming and removal of leaves during harvest.	Nglg Chemicals are not conducive to secondary spread among humans.

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Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traceable to a specific company or industry, the indirect economic impact may be significant (43).	Nglg At the levels at which chemicals are found in food, the impact of contaminated food on the environment is negligible.	Low No previous issues are identified at this stage of production. The lack of traceable cases provides some certainty of the assessment.	**Nglg** Although the impact could be medium and specific data are limited, it is reasonably certain that the overall risk of this hazard is negligible, due to the negligible probability of contamination, and very low probability of exposure.	**To reduce risk:** Keep chemicals away from the cabbage storage area, preferably in a separate building. Keep climate control equipment in good operating condition. Ensure that any cleansing, sanitizing, and disinfectant compounds are used in accordance with approved uses and package directions.

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Post Harvest ***Storage*** Containers of cabbage are stored in refrigerated or unrefrigerated facilities. Cabbages may be stored for up to seven months.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate cabbage. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is unlikely to incorporate extraneous material into its structure. The probability of any physical extraneous material contaminating cabbage at the post harvest stage is negligible.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled prior to consumption, which should remove extraneous material on or near the surface.	Nglg The nature of the physical hazard is not conducive to secondary spread.

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Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traceable to a specific company or industry, the economic impact would be low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage production provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at post harvest is negligible.	**To reduce risk:** Use good storage practices. Protect lights from breakage.

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Post Harvest ***Trimming and Packing*** Remaining portions of the cabbage root are trimmed by hand and the outer leaves are removed. Cabbage is then packed into cardboard containers or sacks.	**Biological** Concern that cabbage could become contaminated during trimming and packing through contact with contaminated workers, the packing area, equipment, and containers. Two foodborne outbreaks of *E. coli* in coleslaw are traceable to restaurants where workers did not wash their hands properly, prior to making coleslaw (102).	Low Worker contact with cabbage during this stage can be a source of pathogens as well as any contaminated equipment or containers. Workers have contact with each head of cabbage at this stage. Data show that people can contaminate produce (31, 50, and 55). The probability of pathogens contaminating the cabbage at this stage is considered low.	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is very low, as most pathogens are found on the outer cabbage leaves, which are often removed prior to consumption (15). Good cold chain management reduces the potential for pathogen growth.	Low Some foodborne pathogens are easily transmitted directly from person-to-person, or by the fecal to oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

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Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly and immune-compromised are at greater risk (21, and 40). Symptoms are variable, from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 25, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility, and size of outbreak (2). If an outbreak is traceable to a specific company or industry, the economic impact for that company could be significant (26, 27, 28, and 69).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med No previous biological hazards attributed to cabbage during this stage are identified. Experience, knowledge of plant growth and the industry, and lack of traceable cases provide reasonable certainty of the assessment.	**Low** The probabilities of contamination and exposure are very low, and the impact of contamination is mostly low. While there is some uncertainty, the overall risk is expected to be quite low.	**To reduce risk:** Keep packing room clean at all times. Have proper toilet and hand washing facilities available for workers. Provide latex gloves to workers when trimming and packing cabbage. Use clean containers. Sanitize knives on a regular basis.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Trimming and Packing*** Remaining portions of the cabbage root are trimmed by hand and the outer leaves are removed. Cabbage is then packed into cardboard containers or sacks.	**Chemical** Chemicals from the packing facility contaminating the cabbages. Contamination from cleaners, disinfectants, and sanitizers. While the level of chemicals in food is usually quite low, it has been suggested that foods are a potential source of exposure to chemicals (35, and 36).	Nglg No chemicals are deliberately applied during the packing stage. Chemicals from cooling machinery or sanitation chemicals may cause contamination, but the likelihood of this occurring is extremely low. The probability of chemical contamination of cabbage at this stage is considered negligible.	Nglg Produce is not identified as a main source of exposure to chemicals and metals (35). Although possible, the probability of consumer exposure to chemicals from this stage of production is quite low (39, 40, and 44). Chemicals may dissipate, degrade or be eliminated through trimming and removal of leaves during harvest and at this stage.	Nglg Chemicals are not conducive to secondary spread among humans.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traceable to a specific company or industry, the indirect economic impact may be significant (43).	Nglg At the levels at which chemicals are found in food, the impact of contaminated food on the environment is negligible.	Low No previous issues are identified at this stage of production. The lack of traceable cases provides some certainty of the assessment.	**Nglg** Although the impact could be medium, and specific data are limited, it is reasonably certain that the overall risk of this hazard is negligible, due to the negligible probability of contamination and exposure.	**To reduce risk:** Carefully monitor the use of all chemicals that could potentially contact the cabbages during the trimming and packing stage. Use only products registered for use and follow label recommendations.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Trimming and Packing*** Remaining portions of the cabbage root are trimmed by hand and the outer leaves are removed. Cabbage is then packed into cardboard containers or sacks.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate cabbage. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is unlikely to incorporate extraneous material into its structure. The probability of any physical extraneous material contaminating cabbage at the trimming and packing stage is negligible.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled prior to consumption, which should remove extraneous material on or near the surface.	Nglg The nature of the physical hazard is not conducive to secondary spread.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traceable to a specific company or industry, the economic impact would be quite low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage production provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at this stage is negligible.	**To reduce risk:** Keep packing room and equipment clean and dispose of debris on a regular basis. Avoid using metal staples for sealing containers.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Transportation, Warehousing and Distribution*** Boxes and sacks of cabbage are loaded onto trucks and transported to warehouses for distribution to retail stores.	**Biological** Concern that cabbage could become contaminated during transportation, warehousing and distribution through contact with contaminated workers, animals, the docking area, equipment, and containers. Two foodborne outbreaks of *E. coli* in coleslaw are traceable to restaurants where workers did not wash their hands properly, prior to making coleslaw (102). Proper climate control during transportation and distribution, and the cleanliness of transportation vehicles are also factors.	Nglg-Low There is some potential for pests to have contact with cabbage during this stage (15). Cabbage packing containers limit contact with pests and other sources of pathogens.	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is very low, as most pathogens are found on the outer cabbage leaves, which are often removed prior to consumption. Good cold chain management reduces the potential for pathogen growth.	Low Some foodborne pathogens are easily transmitted directly by person-to-person, or by the fecal to oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly and immune-compromised are at greater risk (21, and 40). Symptoms are variable, from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 25, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility, and size of outbreak (2). If an outbreak is traceable to a specific company or industry, the economic impact for that company could be significant (26, 27, 28, and 69).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med No previous biological hazards attributed to cabbage during this stage are identified. Experience, knowledge of plant growth and the industry, and lack of traceable cases provide reasonable certainty of the assessment.	**Nglg-Low** The probabilities of contamination and exposure are very low. The impact of contamination is mostly low. While there is some uncertainty, the overall risk is expected to be quite low.	**To reduce risk:** Have proper toilet and hand washing facilities available for workers. Keep cabbage at proper temperature during transportation, warehousing and distribution. Monitor and maintain rodent bait stations regularly. Keep transportation vehicles clean and sanitized. Maintain transportation logs of vehicle use. Avoid shipment with other products that could contaminate cabbage.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Transportation, Warehousing and Distribution*** Boxes and sacks of cabbage are loaded onto trucks and transported to warehouses for distribution to retail stores.	**Chemical** Chemical contamination of cabbage from climate control equipment, cleaners, sanitizers or disinfectants or from cross-contamination during transport. Chemical residues in transportation equipment. While the level of chemicals in food is usually quite low, it has been suggested that foods are a potential source of exposure to chemicals (35, and 36).	Nglg Chemicals are not deliberately applied to cabbage at this stage. Chemicals from cooling equipment or sanitation chemicals may cause contamination, but the likelihood of this occurring is extremely low. The probability of chemical contamination of the cabbage at this stage is considered negligible.	Nglg-Low Produce is not identified as a main source of exposure to chemicals and metals (35). Although possible, the probability of consumer exposure to chemicals from this stage of production is quite low (39, 40, and 44). Chemicals may dissipate, degrade or be eliminated through trimming and removal of leaves during harvest, and prior to packing.	Nglg Chemicals are not conducive to secondary spread among humans.

Risk Characterization			Risk Summary		Recommendations for Action
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traceable to a specific company or industry, the indirect economic impact may be significant (43).	Nglg At the levels at which chemicals are found in food, the impact of contaminated food on the environment would be negligible.	Low No previous issues are identified at this stage. The lack of traceable cases provides some certainty of the assessment.	**Nglg** Although the impact could be medium and specific data are limited, it is reasonably certain that the overall risk of this hazard is negligible, due to the negligible probability of contamination, and very low probability of exposure at the storage stage.	**To reduce risk:** Keep cabbage transportation vehicles clean and sanitized. Do not use vehicles which have previously transported chemicals. Keep climate control equipment in good working order. Ensure that cleansing, sanitizing, and disinfectant compounds are used in accordance with approved uses and package directions.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Transportation, Warehousing and Distribution*** Boxes and sacks of cabbage are loaded onto trucks and transported to warehouses for distribution to retail stores.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate the cabbage. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is unlikely to incorporate extraneous material into its structure. The probability of any physical extraneous material contaminating cabbage at this stage is negligible. Where cabbage is packed in sacks there is greater opportunity for contamination.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled prior to consumption, which should remove extraneous material on or near the surface.	Nglg Physical hazards are not conducive to secondary spread among humans.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traceable to a specific company or industry, the economic impact would be quite low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage production provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at this stage is negligible.	**To reduce risk:** Keep vehicles clean and debris free. Keep distribution and warehouse facility clean and debris free.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Wholesale and Retail*** This stage includes storage, handling, display, and sale at wholesale and retail outlets.	**Biological** Pathogens from the environment absorbed by cabbage. Worker and customer hygiene. Improper refrigeration on display counter, promoting pathogen growth. Rodent activity in stores. Pathogens contaminating cabbage from dirty floors.	Nglg-Low Since cabbage is normally sold loose without any packaging there is some potential for customers to contaminate the cabbage. There is also some potential for cross-contamination between cabbages in the retail display. The cleanliness of the retail store and the amount of handling can also impact the potential for contamination.	Nglg-Low If contamination occurs, the probability of consumer exposure to pathogens is very low as most pathogens will be found on a cabbage's outer leaves, which can be removed prior to consumption, to reduce the level of bacteria (15). Workers and consumers may have contact with many heads of cabbage at this stage. People can contaminate produce (31, 50, and 55). Some retail outlets arrange cabbage in unrefrigerated displays which may increase potential exposure.	Low Some foodborne pathogens are easily transmitted directly by person-to-person, or by the fecal to oral route. If infection occurs, secondary spread among humans can occur. While primary spread may be broadly distributed, secondary spread is expected to be mainly local.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Low-High If infection occurs, the impact is variable depending on the pathogen and individual. The young, elderly and immune-compromised are at greater risk (21, and 40). Symptoms are variable, from mild diarrhea and upset stomach, to extreme cases where death may occur (15, 25, and 101).	Low-Med Direct healthcare costs vary with pathogen virulence, individual susceptibility, and size of outbreak (2). If an outbreak is traceable to a specific company or industry, the economic impact for that company could be significant (26, 27, 28, and 69).	Nglg Although no specific studies are known, the presence of biological hazards in food crops is considered to have negligible impact on the environment.	Low-Med No previous biological hazards attributed to cabbage during this stage are identified. Experience, knowledge of plant growth and the industry, and lack of traceable cases provide reasonable certainty of the assessment.	**Nglg-Low** The probabilities of contamination and exposure are very low. The impact of contamination is mostly low. While there is some uncertainty, the overall risk is expected to be quite low.	**To reduce risk:** Keep display area properly cooled and clean at all times. Monitor and maintain rodent bait stations regularly. Have proper toilet and hand washing facilities available for workers and customers. Maintain proper temperature on display counters to prevent growth of pathogens. Sanitize produce counter on a regular basis. Keep floors clean.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Wholesale and Retail*** This stage includes storage, handling, display, and sale at wholesale and retail outlets.	**Chemical** Contamination from floor cleaners, disinfectants, or sanitizers. While the level of chemicals in food is usually quite low, it has been suggested that foods are a potential source of exposure to chemicals (35, and 36).	Nglg-Low Chemicals are not deliberately applied to cabbage at this stage. Sanitation chemicals may cause contamination, but the likelihood of this occurring is extremely low. The probability of chemically contaminating the cabbage at this stage is considered negligible.	Nglg-Low If contamination occurs, the probability of consumer exposure to chemicals is extremely low, as most chemicals are found on the outer cabbage leaves, which are often removed or washed prior to consumption.	Nglg Chemicals are not conducive to secondary spread among humans.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med The overall impact of chemicals on human health is generally quite low. Chemicals are very rarely found on produce in high enough concentrations to cause acute health effects. Although the effects of long-term exposure to many chemicals are not well known, there is evidence that exposure to certain chemicals over a long period of time can cause numerous health effects including cancer (35, 36, 39, 40, 41, and 42).	Low Direct healthcare costs vary with the level of contamination and exposure. If the contaminant is traceable to a specific company or industry, the indirect economic impact may be significant (43).	Nglg At the levels at which chemicals are found in food, the impact of contaminated food on the environment is negligible.	Low No previous issues are identified at this stage of production. The lack of traceable cases provides some certainty of the assessment.	**Nglg** Although the impact could be medium and specific data are limited, it is reasonably certain that the overall risk of this hazard is negligible, due to the negligible probability of contamination and exposure at this stage.	**To reduce risk:** Ensure that cleansing, sanitizing, and disinfectant compounds are used in accordance with approved uses and package directions. Store chemicals away from the cabbage.

Activity	Hazard/ Concern	Risk Characterization		
		Probability (Likelihood of Going Wrong)		
		of contamination	of consumer exposure	of secondary spread among humans
Post Harvest ***Wholesale and Retail*** This stage includes storage, handling, display, and sale at wholesale and retail outlets.	**Physical** Concern that extraneous physical materials such as metal, wood, rocks, glass, plastic, etc., may contaminate cabbage. Physical hazards in food are known to cause injury (47, 48, and 49). See Appendix C for a list of physical material hazards.	Nglg Cabbage is unlikely to incorporate extraneous material into its structure. The probability of any physical extraneous material entering the cabbage is negligible. Prior to display, cabbage contained in a box is unlikely to become physically contaminated.	Nglg If contamination occurs, the probability of consumer exposure is negligible. Cabbage is generally washed, trimmed and peeled prior to consumption, which should remove extraneous material on or near the surface.	Nglg The nature of the physical hazard is not conducive to secondary spread.

Risk Characterization			**Risk Summary**		**Recommendations for Action**
Impact (Consequences of Going Wrong)			**Uncertainty of Data**	**Summary of Risk and Uncertainty**	
on human health	economic	environment			
Nglg-Med Physical hazards are known to cause injury (47, 48, and 49). If contamination occurs, the impact is variable depending on the physical hazard and individual.	Nglg If contamination occurs and is traceable to a specific company or industry, the economic impact would be quite low.	Nglg The impact of any physical hazards on the environment is considered to be negligible or extremely low.	Low No previous issues with cabbage have been identified. Experience and knowledge of cabbage production, provide reasonable certainty of the assessment.	**Nglg** Although the impact is variable and specific data are not known, due to the negligible probabilities of contamination and exposure, it is reasonably certain that the overall risk at wholesale and retail is negligible.	**To reduce risk:** Keep the display area and produce counter clean and free of debris. Protect lights from breakage. Provide information to employees on physical material hazards.