FINAL REPORT

Feasibility of Alternative Packaging Formats for Nova Scotia Wild Blueberries

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PREPARED FOR:

WILD BLUEBERRY PRODUCERS ASSOCIATION OF NOVA SCOTIA (WBPANS)

PREPARED BY:

N. TREGUNNO
PERENNIA FOOD AND AGRICULTURE INC.

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This was a collaboration with SKU Foods (Peter Chapman), Agriculture and Agri-Food Canada (Dr. Tim Ells and team) and Perennia Food & Agriculture with input from several members of the Perennia team:

Nancy Tregunno, Alexa Jollimore, Hugh Lyu, Pam Laffin, Elaine Grant, Rick Kane, Marsha Grattan, Varvara Satanini, Jancy Stephen and Emily Page.

1. EXECUTIVE SUMMARY

Perennia Food & Agriculture was approached by the Wild Blueberry Association of Nova Scotia (WBPANS) to investigate alternative packaging solutions for wild blueberries. As part of this project, a food safety investigation was completed to look at microbial populations of wild blueberry facilities around NS to assess risk. Furthermore, packaging options for alternate formats were investigated, and a marketing review was completed to highlight a possible path away from selling wild blueberries as a commodity and more like a specialty product.

Samples were collected from several farms for the microbial environmental survey. On-site tests were completed to verify the effectiveness of sanitation at the packing house highlighted areas of improvement such as specific equipment challenges (sizers) as well as overall cleaning technique in some instances. It was found that field totes that have been cleaned often still have organic matter on their surfaces that can potentially contaminate product. In addition, other areas of improvement for overall product quality and extension of shelf life include better temperature control to remove field heat more rapidly/extensively and minimizing mechanical damage. The findings of the microbial survey are detailed in an accompanying report prepared by Dr. Tim Ells, Agriculture and Agri-food Canada (AAFC).

Packaging options need to ensure maximum protection of the blueberries and sustain shelf life. Also, packaging is the main point of contact with consumers, and can differentiate the product from commodity-type packaging through size or material. Examples of options are reviewed both here and in the accompanying report prepared by Peter Chapman, SKU Foods. In terms of fresh shelf life the gold standard is modified atmosphere packaging (MAP). Elevation of CO_2 and accompanying reduction in O_2 within the package slows respiration and prolongs shelf life of many types of produce. Research has shown that MAP could be useful for wild blueberries. A preliminary trial was completed in the summer of 2021 using specialized (laser-perforated) overwrap bags. Results indicate a small improvement in shelf life, despite the fact that the target CO_2 level of 10% was not attained. With more precise perforations and higher CO_2 levels, it is thought that an additional 50-100% of shelf life could be achieved. However, to attempt this type of change in packaging it would be necessary to adopt much more stringent removal of field heat and tighter control of the cold chain. *Expected shelf life (control - no MAP) with good quality berries and proper temperature control i.e.<5C - 10-14 days. Expected shelf life with MAP 14-28 days.*

Microbial levels on berries were within an expected level. Contamination by human sources was not observed. Fecal contamination from fields is a possibility (one sample out of 450 samples) and attention needs to be continued for this potential hazard. Overall recommendations regarding food safety are given, including improved cleaning and sanitation of sizers, totes and harvesting equipment. To grab the attention of customers and consumers, wild blueberries could be presented in alternate package formats that are outside the normal size offering. Packaging options should keep sustainability and function in mind. The "gold standard" for fresh would be MAP and a study completed in 2021 is presented. To offer a fresh berry program, a number of considerations would need to be made including improved cold chain throughout the post-harvest life of the blueberries.

2. BACKGROUND

Wild blueberries from Nova Scotia are often sold for further large-scale commercial processing for commodity pricing, which has been an unprofitable model in recent years. WBPANS, on behalf of the Nova Scotia wild blueberry industry, requested help to explore options to value-add the crop into a minimally processed high quality blueberry product that can be sold directly to retail or other markets, specifically:

(1) a "fresh-frozen" alternative to typical IQF berries (bulk frozen in a dry state, and still free-flowing) and
(2) a wild blueberry fresh-pack (also sorted in a dry state).

These product lines are currently already being pursued by many growers and the intent of this study is to foster additional growth of this model by examining risks and opportunities. These products currently represent a small percentage of the harvest; approximately 4-500,000 lbs fresh-pack and 1 million lbs fresh-frozen and are mostly sold in 5 lb boxes.

Three aspects of these alternatives have been explored:

(a) **Food Safety and Quality** - in collaboration with Agriculture and Agri-food Canada (AAFC)
(b) **Packaging and Equipment** based on discussions with suppliers and in-house knowledge regarding food-package interactions and sustainable packaging
(c) **Marketing** - with partner SKU Foods, building on current marketing reports supplied by WBPANS.

Farms were surveyed prior to the season to understand their current practices. During the 2021 blueberry season five farms were visited to obtain samples and complete swabbing of surfaces. The Food Microbiology group at AAFC partnered with Perennia to complete a microbiological survey of these samples and swabs. To address possible shelf-life extension of fresh wild blueberries, a modified atmosphere packaging (MAP) study was completed at Perennia. In addition, we have partnered with SKU Foods to review opportunities in the market to move wild blueberries from a commodity to a specialty item.

3. SURVEY

Six wild blueberry farms were surveyed and four of them went on to participate in sampling. All six farms participate in production, harvesting and packing.

Table 1. Survey results from 6 wild blueberry farms in three NS counties, 2021.

Farm parameters	***# Farms out of 6 / Details***
CFIA licenced, with preventative control plan (PCP)	2
Third party certifications	Canada GAP (1); Use Canada GAP model but uncertified (1); Organic (1); None (3)
Traceability	4
Volume fresh / fresh-frozen <10,000 lbs 10,000-50,000 lbs >50,000	 1 4 1
Acreage fresh / fresh-frozen	4500 to 700,000 acres
Existing packaging	5 lbs boxes (majority) waxed or "Enviroshield" type compostable protective layer Other boxes: 2.5, 3 and 10lbs Plastic tubs: 1 kg, 2.5, 5 and 10lbs Stand-up pouches (SUP): 500g, 1.5kg Pints: paperboard
Markets	On-site and adjacent markets (3) Farm markets (1) Inter-provincial/retail/farm markets (2)
Value-added	2
Microbial testing completed	2

Field / packing shed parameters	***# Farms out of 6 / Details***
Harvesting for fresh and fresh-frozen	Hand-rake (3); modified mechanical (1); walk-behind harvester (2)
Field contamination (wildlife)	Deer, birds, bear, fox, coyotes, ants
Tactics to deal with droppings	Avoid in field, go around it. If on line, clear line and clean off line after, use scare owls, avoid strip of field next to woods (too many droppings)
Washrooms	Proper separation and handwashing stations observed.
Window of time between harvest and shed	1 to 6 hours
Travel to shed	Covered truck, open truck. Some use cart or 4-wheelers to get to shade or to trucks. Most use shade to minimize direct sunlight.
Cooling at shed	Cooling is minimal. Geothermal (1), AC (1), heat pump (1) ambient air with movement from fans (others). Temperature in sheds not below 18°C, usually higher.
Maximum drop height	Lowest "max" was 2". Highest was 6" or 12" with air.
Hairnets	4
Aprons	1
Footbaths	If traffic to adjacent livestock is possible, sanitizing footbaths should be in place (2)
Food safety training	5 (one farm had more of an orientation)
Sanitation	Variety of procedures. See further info on sanitation section.

Sanitation

Current practices vary. Issues that were noted:

- Non-food-grade cleaner used at one facility. (Has been addressed by processor).
- Cleaning and sanitation steps sometimes completed together – these should be two separate steps.
- Generally difficult to clean certain parts of the line especially sizers due to concern around chemicals breaking down the material (reportedly peroxide or chlorine can be problematic on sizer) and/or due to crevices.
- High pressure hoses are used in some facilities and can be problematic. A certain volume of water is required to remove cleaning residue and often not achieved with high pressure hoses. Secondly high-pressure wash can spread contamination onto clean surfaces.
- Procedure to mix cleaner/sanitizer in some cases not documented.

- Not all facilities have record keeping for cleaning and sanitation
- Totes are frequently not sufficiently cleaned / sanitized (sometimes scratched and could harbour contamination).
- Employee training – noticed someone picked an item up off the floor and did not wash hands before returning to picking belt. These types of things need to be addressed in training.

4. FOOD SAFETY

a. Swabbing at packing sheds

Perennia staff swabbed food contact surfaces, which included packing line and field totes, using a surface hygiene test system (ATP Clean-Trace, Biotrace, 3M). This procedure tests for adenosine triphosphate (ATP) to verify the effectiveness of cleaning. ATP is an energy-carrying molecule found in all living organisms and proper cleaning should result in a low reading. Swabbing was completed on cleaned (and where applicable, sanitized) surfaces. A 10 cm^2 area was swabbed using Clean-Trace 3M UXL100 swabs which were read on-site to get Relative Light Unit (RLU) readings to determine how effective current cleaning practices are. The 3M Company states that there are no set limits for RLU values (can vary by commodity / product), but that commonly used thresholds after cleaning and sanitation of food contact surfaces are:

<150 RLU = ACCEPTABLE
150-300 RLU = CAUTION
>300 RLU = FAIL

Results:

The RLU values varied by location and also by visit. In some cases, the RLU values showed that cleaning of surfaces was highly effective. In other cases, the levels were much higher than desired. Swabbing of belts was attempted in the morning after evening sanitation. In two cases this was not possible and the swabbing was done after a lunch clean up. In both cases those RLUs were substantially higher than the other visits which had been in the acceptable range. 3M advised that some sanitizing agents can interfere with readings, and it is best to do the swabbing after cleaning and before sanitation, or well after (e.g. the next morning). Data from belt swabbing for initial visit at Farm 1 and final visits at Farms 2 and 4 were removed for this reason as the tests were done immediately after sanitation and read much higher than on other occasions. In two cases, sizers had much higher readings than the other areas (2 log cycles higher and 1 log cycle higher, at two different farms. In the initial interviews, farms commented that equipment suppliers had told them that they should avoid chemicals (chlorine or peroxide). Some farms use only water and physical scrubbing. This is acceptable if the clean surfaces can be verified. In many cases cleaning of the sizer is an area for improvement.

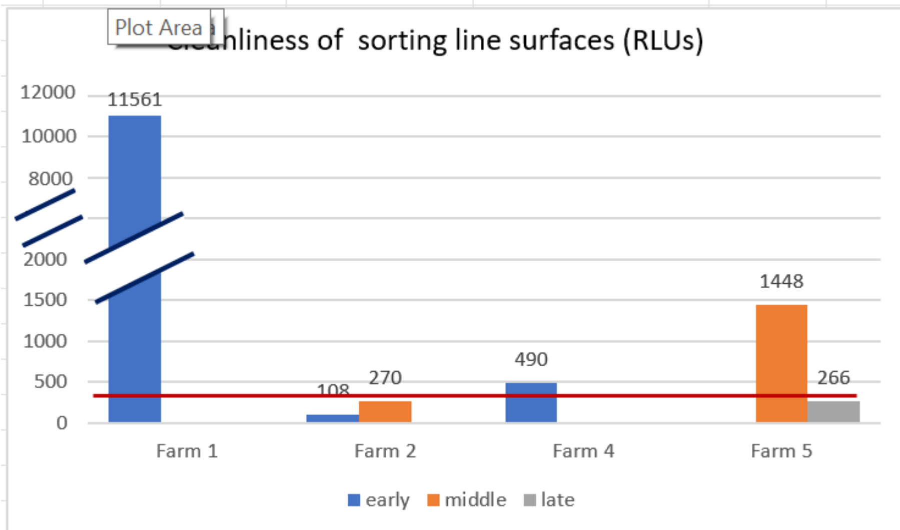

Figure 1. Relative Light Unit (RLU) values for Clean-Trace 3M™ swabs taken on cleaned/sanitized sorting line surfaces including receiving belt, tilt belt, sizer and sorting line (various locations averaged n=5 per visit). The red line (300 RLU) indicates a commonly used "fail" value for cleaned/sanitized food contact surfaces. Three data values were removed due to sanitizer interaction (thought to be false high readings) when taken directly after sanitation which can cause interference.

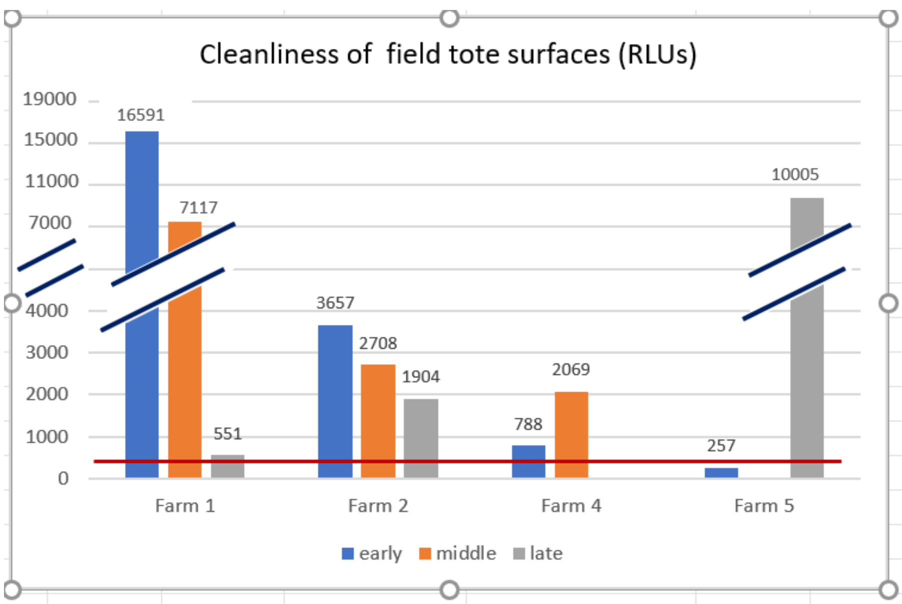

Figure 2. Relative Light Unit (RLU) values for Clean-Trace 3M™ swabs taken on cleaned/sanitized field totes surfaces (various locations averaged n=5 per visit). The red line (300 RLU) indicates a commonly used "fail" value for cleaned/sanitized food contact surfaces.

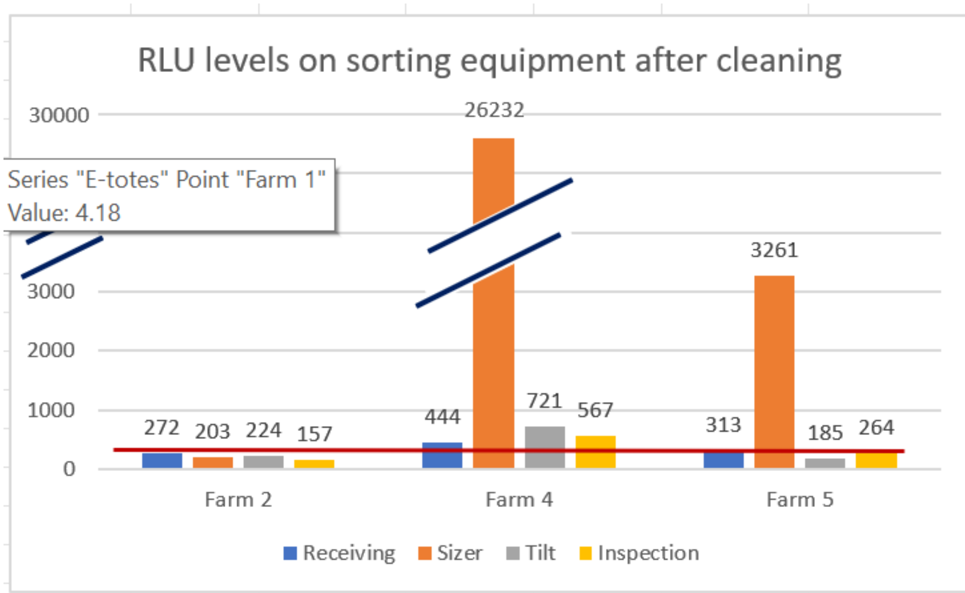

Figure 3. Relative Light Unit (RLU) values for Clean-Trace 3M™ swabs taken on cleaned/sanitized processing surfaces at Farms 2, 4 and 5 (average n= 2, n=4 for inspection belts). The red line (300 RLU) indicates a commonly used "fail" value for cleaned/sanitized food contact surfaces.

b. Environmental survey – see AAFC report

c. Food Safety, Quality and Sanitation Recommendations

Depending on your market and customer base, you may need a written program. Perennia has created an easy-to-follow guide called, "Safe Food for Canadians, Good Agricultural Practices Guide, A GUIDE TO MEETING THE SAFE FOOD FOR CANADIANS' REGULATIONS FOR FRESH FRUIT AND VEGETABLES". This guide is meant to be a tool to help your farm/packhouse meet the Safe Food for Canadians requirements. If your company is still growing, this guide provides an excellent resource to improve market readiness.

Sanitation is a determining factor related to your shelf-life; a clean environment ensures your product has the best chance to maintain its shelf life. To maintain a hygienic environment, please use the information provided. If you do not have a sanitation program and want to create one, use the resources available in the guide to help, get you started. Included in the appendix of the guide are sections on *How to Draft an SOP/Policy/Procedure*, *Sanitation Records,* guidance on *Traceability,* and an *Environmental Swabbing Plan (procedure and records)* to name a few. There are sample forms available for you to use. They are downloadable, easy to modify, or you can customize to your needs.

Sanitation in Pack houses

Main sanitation concerns regarding pack houses and equipment are improper or inadequate sanitation procedures or the use of improper chemical concentrations, as this can lead to contamination of food, ingredients, packaging materials and food contact surfaces. By using the following information, you can start to build or strengthen your existing sanitation program.

- **Ensure schedules and clear procedures are in place.**

Sanitation schedule and frequency must be in place for all equipment at the farm, including harvest and pack equipment as well as reusable containers, utensils & tools (i.e., hand rakes), removal of waste, work gear, wagons/carts etc. (i.e., daily, weekly, monthly, pre and postseason). Cleaning and sanitizing procedures must include methods for dry cleaning, pressure washing- ensuring aerosols do not contaminate clean surfaces, chemicals used, concentrations, PPE, proper handling, etc. *as well as* sanitation records.

Pre-operational/post-operational inspection procedures: after cleaning and before the product is handled, the harvest/pack area, storages, and equipment (where applicable) are clean and free from dust, dirt, food debris and excessive grease.

Record keeping is best practice. By recording the cleaning as it is occurring an operation will be able to determine how the activities were conducted should there be a problem.

- **Ensure chemicals are approved for use in a food establishment (i.e., harvest equipment and packhouse).**

When purchasing chemicals from a Chemical Company the price may be higher but the value for their expertise and support is well worth the increased cost. The resources that come with these companies include the ability to provide training, recommend which chemicals to use at what concentration. Most companies will guide and train you on how to use and verify and help you to use the chemicals efficiently and effectively. A good sanitation program is one way to give your product the best chance for maximum shelf life.

When mixing chemicals, it is always a good practice to trace how much is used and make sure the strength is appropriate and verify the sanitizer is the correct concentration (leave on or rinse off).

- **Clean field equipment away from harvest areas, remove or move packaging and product away from the area being cleaned before cleaning packhouse equipment and surrounding areas.**

Packhouse:

Specialized equipment including flexible individual belts and moving parts may need manufacture's recommendations for cleaning using compatible chemicals and methods, (gentle wipe as opposed to water or high-pressure rinse). Consult the manufacturers and chemical representative for specific details.
Detailed cleaning means the equipment needs extra care taken i.e., cover sensitive parts or electronics wash/wipe individual strand/cords of the belting system and other moving parts that may need extra care and attention.

Field equipment:

Harvesters, totes, and conveyances: the condition of your equipment will determine how clean it will be when you have completed sanitation. Scratches or rough surfaces or those with gaps are harder to clean. Scratches create harborage points for bacteria to grow. **Smooth, cleanable, and impervious** are 3 words to remember for surfaces in a food facility.

The data gathered from ATP swabbing food contact surfaces at the packhouse is a great snapshot of cleaning practices however, to achieve historical values and verify trending of results, the sampling would need to be increased with consistent timing and frequency, that way a clearer comparison can be made.

- **Ensure field areas are checked for signs of debris, wildlife activity and foreign material before harvesting activities take place.**

Include a brief description of how this is completed and record any issues you encounter i.e., before harvesting, this can be done by visually inspecting to avoid areas that may be contaminated.

- **Provide the necessary training of staff.**

Employees' training is critical to their understanding and compliance with good agricultural practices. Your product is literally "in their hands"; employees are part of the process and need to maintain a hygienic environment, this also contributes to the final shelf life and quality of your product.

5. MARKETING – see report from SKU Foods

6. PACKAGING ALTERNATIVES

Fresh

In addition to capturing the eye of the consumer, the functions of a fresh blueberry package are to contain the product, catch any excess moisture and retain enough moisture that the berries don't dry out. Extra benefits could be showing the product and modifying the atmosphere to extend shelf life. Companies also need to consider the importance of sustainability of their packaging and ideally should offer a recyclable or compostable package.

Current pack formats are primarily 5 lb **cardboard boxes**. To assist with retention of humidity these are waxed or have an alternative compostable coating such as Maritime Paper's Enviroshield. As opposed to the "curtain coated" paraffin wax which makes the package non-recyclable, the Enviroshield or other recyclable option is a wax-alternative coating that is fully recyclable and performs just as well as wax. According to Maritime Paper, their Enviroshield boxes are actually less expensive than traditional waxed cardboard (by 34% in 2021) so this should be the clear choice if packers are using cardboard boxes. Other companies such as Verativ Canada supply similar boxes. Waxed cardboard is not recyclable which is a key factor most consumers are looking for in packaging. Group ordering is available to reduce costs. If a new size was desired, ordering >15,000 units would give a price break (Maritime Paper, direct communication). Fibre board pints are also common. Retailers expecting covers on fruit has made this offering more complex.

Table 2. Examples of packaging options for fresh blueberries.

Fresh package type	Pros	Cons	Considerations*
Cardboard w compostable coating	Drip containment Recyclable Larger family size Can go to freezer	Hard for some consumers to use in 3-7 days Low margin for seller	Consider alternate size e.g. 2 lbs Group ordering
PET	PET (#1) is fully recyclable Can see product May be cheapest Can attach film or use lid	Plastics perception/ban Not good for leaking fruit; may require pad Not suitable for longer-term frozen storage	Ensure recyclability with supplier, some contain clarifying agents Hinged clamshell Potential use as a MAP package (base with lidding film) ~$0.18
Sealable fibreboard	Appeals to natural/local Compostable Drip containment Fruit visible through cover	Retailers looking for covers on fruit	Covers can be separate plastic or lidding film if a land area available (like CSK containers) Potential use as a MAP package ~$.??
Fibreboard (green pints)	Appeals to consumers for natural/local Compostable Drip containment Fruit visible through cover	Retailers looking for covers on fruit, difficult to do with this package	$0.08
Sugarcane	Appeals to consumers for natural/local Compostable Drip containment Fruit visible through cover	Imported from overseas	Covers can be separate plastic or lidding film if a land area available (like CSK containers) $0.18

**approximate costing based on 100,000 one-pint containers*

Frozen

The job of a frozen blueberry package is to contain the product and prevent moisture and oxygen transfer (prevent "freezer burn"). A flexible package or one that fits easily into a small home freezer is of value to consumers. Extra benefits could include showing the product. Ideally all packaging should be recyclable.

Currently pack formats are primarily 5 lb cardboard boxes. This package achieves a frozen shelf life of approximately a year. Some packers are also packing in stand-up pouches (SUPs). If these are made with mixed materials, they will not be suitable for the recycling stream, even though some suppliers may indicate that they are recyclable. It is a matter of availability of markets that can accept each material, and the most readily recyclable forms of plastic in the world are #1 (PET), #2 (HDPE) and #4 (LDPE) with #5 (PP) being accepted in most markets.

Table 3. Examples of packaging options for frozen blueberries.

Frozen package type	Pros	Cons	Considerations
Cardboard with compostable coating	Drip containment Recyclable Larger family size Can go to freezer	Hard for some consumers to use in 3-7 days Low margin for seller	Consider alternate size e.g. 2 lbs Group ordering
Stand-up pouch	Only readily recyclable if using mono-material pouch Great fit for consumers' freezers Good moisture and oxygen barrier properties	Plastics perception/ban Requires filling equipment and larger scale orders Aligns product with commodity-type products	Ensure recyclability with supplier, request mono-material PE plastic Co-packing available locally (e.g., Knol Farms)
Single-use LDPE pouch in paperboard	Recyclable packaging Convenient Attractive and different from commodity	Slightly less protection from oxygen and moisture transfer	Despite less barrier properties seems to offer a suitable shelf life (1 year to be validated) Co-packing available locally (e.g., Knol Farms)

Currently most stand-up pouches are not recyclable. However, there is new technology available (possible suppliers include Farnell Packaging and Verativ) that uses only one material (PE polyethylene) and is 100% recyclable and "pre-approved" with the How To Recycle logo from Sustainable Packaging Coalition (Farnell

Packaging). Despite the lack of nylon or other barrier layer these pouches have similar barrier properties to other multi-layer stand-up pouches. This should be the #2 plastic, PE, which is readily recyclable globally.

Packaging from Knol Farms (available to co-pack other brands) includes stand-up pouches and also a multi-pack 6 x 57g in LDPE bags that go into a paperboard box. This is very convenient for consumers who may not be motivated to purchase a large box for the freezer but might make this a regular purchase for easy servings. This packaging is fully recyclable. Knol has a filler to fill these bags and is open for business to co-pack for others.

6. MAP STUDY

This section will outline background research on MAP previously done by others plus outline our results from a trial done in summer of 2021.

Background:
Only about 1% of the wild blueberry crop in Nova Scotia is sold fresh. In addition to a short season, shelf life is a large hurdle to providing fresh fruit to retail markets. The smaller berry size makes them more compact and subject to more touch points from adjacent berries. Their skins are also thinner than their cultivated counterparts and they are generally more susceptible to damage.

Apart from their inherent sensitivity, three main challenges to achieving an acceptable shelf life for fresh pack (as per Dr. Charles Forney, post-harvest specialist, AAFC, personal communication) are:

1. Ability to control post-harvest temperatures
2. Mechanical damage from both harvesting and drops throughout the process
3. A range of storability and ripening stages due to genetic diversity in the field

Temperature is considered a critical parameter for maintaining shelf life. The importance of cooling to reduce field heat, slow respiration and delay physiological deterioration is well understood in the produce industry. The challenges of maintaining cold temperatures and effects of delayed removal of field heat were outlined in a recent study on NS blueberries (Dr. T. Esau & Dr. A. Farooque, 2020, WBPANS report) where firmness was shown to drop considerably with delayed cooling. Negative effects from delayed or insufficient cooling have been documented in previous studies (Jackson et al., 1999; Calderwood and Tooley, 2020). For example, it is recommended to place berries in the shade within an hour of picking, which can keep berries 5.5°C cooler than if in direct sunlight and can make an overall improvement in quality (L. Calderwood, June 2020). Getting fruit to the packing shed in a timely manner and removing field heat is required in order to slow respiration and prevent decay. This is a major limiting factor the industry would need to solve to be able to extend shelf life of fresh-pack berries.

The infrastructure in Nova Scotia is not currently suited to obtaining extended shelf-life. Currently many operators maintain a “cooler” temperature of about 17-23°C in their packing house. To optimize shelf-life it would be appropriate to pre-cool berries to and maintain a cold temperature from time of packing throughout the storage and distribution chain. Ideally, many soft-fruit companies packing other types of cold-storable fruit target a packing temperature of 5°C and then maintain a storage temperature of 0-4°C. Alternatively, to better accommodate the comfort of employees, fruit will often be cooled to 10°C then packed in an environment of 10°C with further cooling of packed product to 0-4°C. It is important to minimize fluctuations in storage temperatures; if cooled product goes back up in temperature then condensation can occur which can accelerate decay.

Mechanical damage of fruit comes from both harvesting equipment, where mechanical harvesting can have a greater impact than walk-behind harvesting or hand raking, and processing steps where drops are incorporated throughout the process to move fruit from one stage to the next. In highbush blueberries, a 44% reduction in yield of marketable fruit was noted for mechanically harvested berries over hand-picked (Mainland et al., 1975 in Sanford et al., 1991). Dropping from a height causes both bruising and splitting. Bruising causes a rapid decline in fruit firmness as cell membranes are ruptured. Splitting of skins allows leakage of juices which can encourage growth of yeast and moulds, accelerating decay. Both bruising and splitting shorten overall shelf life. Specific impacts of these mechanical effects on blueberry quality have been outlined by Sanford et al. (1991) and Xu et al. (2015).

The diversity of species of wild blueberries was mentioned by Dr. Charles Forney (Agriculture and Agri-food Canada, personal communication) as an important consideration since one particular lot of fruit may have many different genotypes. Even within a small area in a field, genotypes are mixed which means they possess different storability as well as different ripening times. There could be both under-ripe and over-ripe berries in a lot which is very challenging to work with. Mixed genotypes are important to consider but cannot easily be controlled.

At the current time, processors in NS reportedly attain a shelf-life of about **5-7 days** under refrigerated distribution and storage conditions. Under ideal harvest conditions of harvest with pre-cooling and maintenance of cold-chain throughout handling and storage, a shelf life of up to **one month** can be attained, according to the University of Maine publication “Post-harvest Handling of Wild Blueberries”. (https://extension.umaine.edu/blueberries/post-harvest-handling/)

To make the fresh-pack offering more commercially viable, **if** low temperatures could be sufficiently maintained and mechanical damage from harvesters and drops minimized, MAP could be used to extend shelf life. Similar to controlled atmosphere (CA), used widely in bulk storage for apples, pears and other fruits, MAP creates an environment with lower oxygen and higher carbon dioxide to lower the product's respiration rate and slow senescence.

Prange et al. (1995) found that two cultivars of lowbush blueberries (Blomidon and Fundy) that were held in 15% CO_2 and 1-5% O_2 had 7 and 9% unmarketable fruit after 42 days whereas the air-stored control had 36% and 30% unmarketable fruit. They attained a 28-day marketable shelf life (<3% defects) under these conditions (at 0°C) as opposed to 14 days for the ambient air (0°C) control samples. Koort et al. (2018) conducted MAP trials on lowbush and half-highbush blueberries in Estonia using perforated overwrap bags over perforated PET perforated clamshells to achieve an atmosphere of 8% CO_2 and 9% O_2; this extended shelf life of lowbush blueberries (Northblue cultivar) from 22 to 37 days (however criteria was less strict where marketable shelf life was defined as <10% shrivelled and <5% decayed). Recommendations from Madrid and Beaudry (2020) state optimal modified atmosphere (MA) conditions of 15% CO_2 (with 6% O_2) for highbush blueberries. However, they also recommend tight preservation of the cold chain, storage of 0-2°C and rapid cooling down to optimal temperature within 2h of harvest using a cooling tunnel and mention that temperature oscillations through the cold chain will result in condensation causing quality issues. For highbush blueberries, pallet MAP is now common on many continents (and has been done successfully here in NS for 20 years) and punnet-sized MAP systems are less widely used.

A supplier who has taken MAP to the next level is "PerfoTec" from the Netherlands. They sell equipment that measures the respiration rate of each lot of fruit (lot to lot variability means that respiration rates can vary considerably). Then they match the respiration rate of the lot to the amount of perforations in the lidding of the packaging material, to optimize the headspace of the packages to ensure the best possible outcome. By tailoring the perforations in the lidding material to create an ideal headspace for each lot, the company claims that can achieve almost a doubling of shelf life for soft fruits such as strawberries and highbush blueberries. The PerfoTec representative was clear that they **will not sell their equipment to processors who do not have good temperature control, because the technology does not perform successfully if temperatures are greater than 5°C**.

Part of this project was to determine, under optimized circumstances, what shelf life could be reasonably attained for fresh wild blueberries. In summer 2021, MAP packaging was tested on Nova Scotia wild blueberries. Berries were obtained from a packing shed in Antigonish County after harvest by a walk-behind harvester, in-line blowing, sizing and sorting. Fruit was transported to the Perennia Innovation Centre and weighed, then placed into overwrap bags (two perforation levels) from StePac Packaging Company (Israel).

The CO_2 target was 10-12% based on UC Davis recommendations (Kader et al., 2002). The suggested target for O_2 is 1-5%. This is for highbush berries, but work done by Prange et al. (1995) found 15% CO_2 and 1-5% O_2 to be effective levels for preventing unmarketable fruit.

Fresh Pack MAP trial for wild blueberries – Summer 2021

Purpose: to compare wild blueberries in modified atmosphere with those held in ambient atmosphere to determine if shelf life extension is possible and to what extent.

- *Vaccinium angustofolium* (wild blueberries) were harvested using a walk-behind harvester. The berries had been picked in the evening (Aug 22), held in plenum with air movement overnight and were blown, sorted and collected around 8AM on Aug 23.
- Berries were packed into 1 pint vented PET clamshells and placed into coolers with ice packs and transported to Perennia Food & Beverage Innovation Centre
- Clamshells were packed in secondary packaging XTEND overwrap bags from Stepac (Israel)
- Treatments were as follows:

1. **TEN each 4 x 300g (1 pint) clamshell placed in cardboard tray inside Xtend bag #1**
2. **TEN each 4 x 300g (1 pint) clamshell placed in cardboard tray inside Xtend bag #2**
3. **TEN each 4 x 300g (1 pint) clamshell placed in cardboard tray (CONTROL)**

Storage was at 4°C+/-1°C. Samples were (destructively) analyzed three times per week for two weeks (at which point decay was >8%).

Subjective assessment:

1. Appearance using grading sheet including weight of defects
2. Sensory assessment
3. Firmness scale
4. Photos of samples

Objective assessment:

1. CO_2 and O_2 level in headspace (***Optimal CO_2 level 10-12%).***
2. Weight
3. Titratable acidity
4. Brix

Results:

The berries obtained on Aug 23 were in "good" condition but not excellent due to soft / split berries, likely due to high temperatures (defect rate was already 2.7% on day 0). Also, although the packaging supplier (Stepac) made an estimate based on work done with highbush blueberries, the overwrap bags provided had too many perforations therefore it was not possible to obtain the target CO_2 (10-12%). Instead, a maximum CO_2 of 2.5% was achieved. Elevated CO_2 levels are known to decrease respiration rates of the fruit and therefore slow senescence. Even with a small increase in CO_2 it appears that shelf life was impacted. Keeping in mind this was a preliminary study and that it is important to be able to replicate results and show impact repeatedly, this is an encouraging illustration:

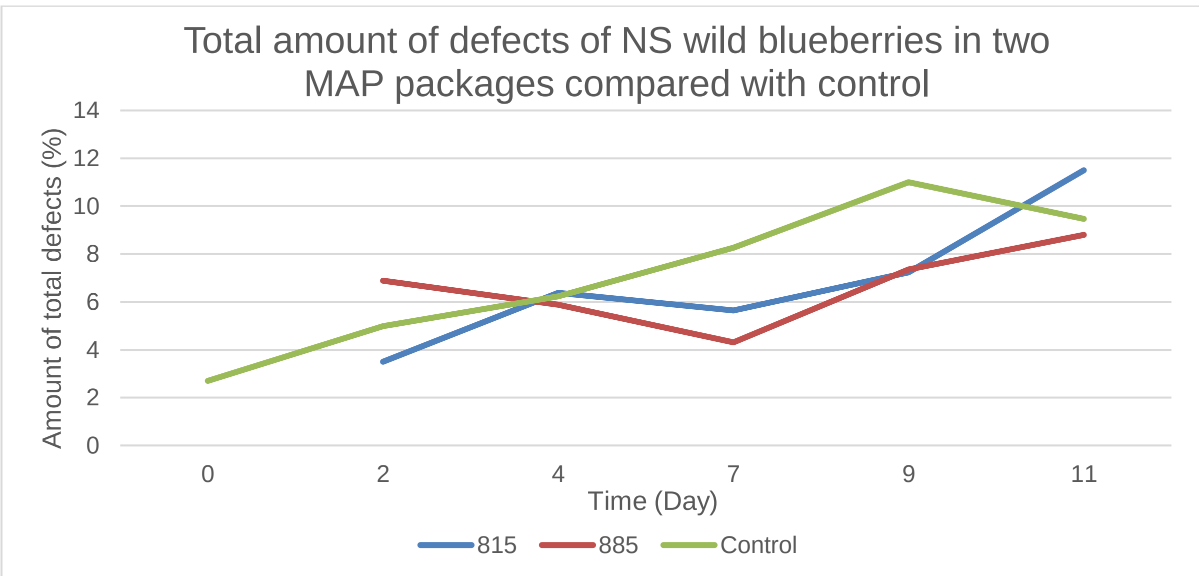

Figure 4: Impact of MAP on berry quality with two perforation levels and control with no overwrap bag (815 bags have less perforations, 885 have more perforations). Defects were split, bruised or shrivelled berries.

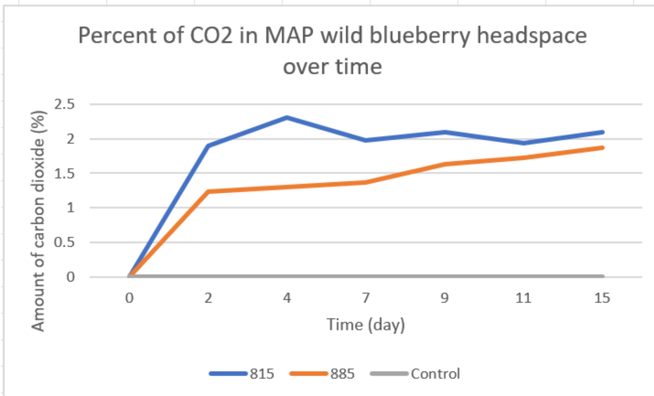

Figure 5: CO2 levels inside MAP package.

Approximate Capital Costs for MAP:

Equipment	Supplier	Ballpark pricing	Details
Topseal (machine + tooling)	Proseal	USD $64,500 = CAD $82,600 OR	Semi-automatic, requires operator
		USD $150,000= CAD $192,000	Fully automatic
Laser Perforation System (machine + install + 1yr service)	Perfotec	69,000€ = CAD $96,000	Selects perforation frequency based on respiration rate of lot

7. RECOMMENDATIONS

Overall, results indicated that Nova Scotia wild blueberry operations had acceptable conditions but that some improvements could be made in some cases.
In order to further improve quality, reduce risk and extend shelf life, the following are suggested.

Field

- minimize physical damage / drops (try to keep to less than 2" or other ways to minimize impact)
- minimize time to cooling (use of shade, rapid transport to packing shed, removal of field heat). Use cool air pulled across berries to remove field heat. See further information on cooling suggestions including use of the inexpensive small-scale cooler "CoolBot" in the University of Maine Wild Blueberry fact sheet Post-Harvest Handling of Wild Blueberry.
- train employees to avoid fecal contamination and on procedure to follow if encountered

Packing House

- Sanitation program – document procedures and execution; train staff each season on sanitation and hygiene.

- Footbaths should be in use if livestock is nearby
- It is possible for contamination to occur as shown by 1/400 final packages tested. Ensure training, good lighting (trying to get a spec on this) for sorting belts, slow enough flow, training for staff to recognize hazards
- Sorting line cleanliness varied from visit to visit and from farm to farm. One farm met the suggested maximum "RLU" level for ATP testing which indicates overall cleanliness on two visits out of two. Other farms had at least one occasion where they were above the suggested level. In two cases, the sizer was where the counts were above the suggested level (bringing the average level up). This is an area for improvement.
- Field tote cleanliness varied from visit to visit and from farm to farm. All farms had at least one instance where they were well above the recommended RLU level. One farm achieved the suggested level on their own totes but was above for shared totes (go to processor).
- Cleaning following proper procedures using verification such as ATP to ensure its effectiveness. Resources include equipment supplier (cleaning procedures for specific pieces of equipment), cleaning/sanitation supplier, perennia staff. (Our Quality and Food Safety team works with clients to assist with the development and implementation of hygiene monitoring programs).
- Instructions to wash berries before consuming on outside of box would be a prudent addition to the label.

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Other Resources:

Nova Scotia Wild Blueberry Best Management Practices:
https://www.perennia.ca/BlueberryBMP/blueberrybmps.html

Safe Food for Canadians, Good Agricultural Practices Guide:
https://www.perennia.ca/wp-content/uploads/2020/12/Safe-Food-Canadians-Guide-DEC8.pdf

Mitcham, E.J., C.H. Crisoto, and A.A. Kader, 1998. Bushberries: Recommendations for Maintaining Postharvest Quality. Postharvest Center University of California, Davis. https://postharvest.ucdavis.edu/Commodity_Resources/Fact_Sheets/Datastores/Fruit_English/?uid=12&ds=798

Bulletin #4282, Food Safety Best Management Practices for Wild Blueberry Producers in Maine. https://extension.umaine.edu/publications/4282e/

Co-operative Extension, University of Maine, Post Harvest Handling of Wild Blueberry. https://extension.umaine.edu/blueberries/post-harvest-handling/