REPORT CDOT-2023-17 November 2023

Deicing Field Trials: Use of Locally Sourced Cheese Brine

APPLIED RESEARCH & INNOVATION BRANCH

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COLORADO Department of Transportation

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16. Abstract

Leprino Cheese Brine (LCB) was approved for use in field trials at two locations in Colorado as a pre-wetting agent added to solid material (salt-sand or rock salt) at 8 gal/ton. Three attempts were made to pick up and then apply the LCB as a pre-wetting agent. While one successful pick up and application occurred, it was not as a pre-wet. The two additional pickups and field applications were attempted, but were unsuccessful due to clogging of tanks, lines, filters, and pumps by the LCB. To provide consistency in the product and procedures and prevent clogging of tanks and application equipment, quality control of LCB by Leprino Foods is needed and tanks and application equipment need to be sufficiently clean.

Overall, the cost analysis shows that if LCB is picked up in large quantities and can offset the use of large volumes of Apex, there is potential cost saving for CDOT. For this to occur, LCB needs to be successfully picked up and applied as a pre-wetting agent. The challenge of the LCB clogging the tank, lines, filters, and pumps was the primary roadblock preventing successful implementation of this project.

Use of LCB by CDOT has potential to reduce costs for CDOT and reduce the amount of salt brought into Colorado, that ends up in the environment.

The creation of an improved LCB for use as liquid anti-icer was investigated. After significant investment, the development of the improved LCB was abandoned due to increased requirements and costs.

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Executive Summary

Leprino Cheese Brine (LCB) was approved for use in field trials at two locations in Colorado as a pre-wetting agent added to solid material (salt-sand or rock salt) at 8 gal/ton. Three attempts were made to pick up and then apply the LCB as a pre-wetting agent. While one successful pick up and application occurred, it was not as a pre-wet. The two additional pickups and field applications were attempted, but were unsuccessful due to clogging of tanks, lines, filters, and pumps by the LCB. To provide consistency in the product and procedures and prevent clogging of tanks and application equipment quality control of LCB by Leprino Foods is needed and tanks and application equipment need to be sufficiently cleaned by CDOT.

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Use of LCB by CDOT has potential to reduce costs for CDOT and reduce the amount of salt brought into Colorado, which then ends up in the environment.

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Introduction

Building on work by this research team that investigated the mechanism by which ag-based deicer additives work to improve deicer function (Muthumani et al., 2015), followed-up by the Colorado Department of Transportation (CDOT) research project *Comparison of ag-based deicing additives* (Fay et al., 2022), this implementation and research effort investigated the use of locally sourced ag-based deicing additives. Ag-based products, or agriculturally derived by- or co-products, can be derived from beets, apple pulp, pulp/paper plants, potato (vodka co-products), and peonies, as well as other sources such as waste brines from cheese manufacturing. When used in conjunction with traditional deicers, these ag- based additives can provide benefits including corrosion protection, longevity on the pavement surface, and improved product performance through suppressed ice nucleation (Fay and Akin, 2019; Fay and Akin, 2018; Muthumani, Fay and Shi, 2016; Muthumani et al., 2015).

Fay et al. (2022) identified Leprino Foods cheese brine (LCB) as a viable, locally sourced by-product that can be used as a pre-wetting additive in winter maintenance operations. Laboratory testing determined that LCB provides beneficial qualities typically found in ag-based additives as well as provides a moderate level of chlorides (about 13% NaCl concentration). A collaborative effort by Leprino Foods, CDOT, and this research team worked toward, and was granted, a beneficial use permit by the Colorado Department of Public Health & Environment (CDPHE) allowing CDOT to use LCB as a pre-wetting additive in two field trial locations.

The objective of this effort was to implement the results from Fay et al. (2022) through field trials, in which CDOT used LCB as a pre-wetting agent. This effort included data collection from the field trials on the effectiveness, costs and savings, and other benefits from the use of LCB compared to existing practices by CDOT. In addition to this, this effort investigated the feasibility of "improving" the LCB by removing key elements that do not allow the product to pass standard specification, for example, phosphorus and other elements of concern in Colorado (CDPHE 2023), so that it can be used for direct liquid application or anti-icing. This report documents the process of "improving" LCB, the laboratory results, and the materials developed for the beneficial use permit application for the use of improved LCB as an anti-icing liquid.

Task 1 Prewetting Field Trials

The research team evaluated the use of LCB as a pre-wetting agent in controlled field trials. This effort included supporting CDOT and Leprino Foods as was needed prior to and during field trials, supporting the collection of LCB samples for testing, setting up and coordinating meetings between organizations, and data collection from the field trials. The Field Trial plan developed for CDOT can be found in Appendix A – CDOT Leprino Cheese Brine Field Trial Plan.

Field Application of LCB as a Pre-wetting agent

Two field trial locations were identified and approved by CDPHE:

- Brush, CO - US 34 from mile marker (MM) 159-180.7, Hwy 71 from MM 175.5-181.4, and Hwy 6 from MM 371-380.5 (Figure 1)
- Hudson, CO - I-76 frontage road from MM 25-31 (Figure 2)

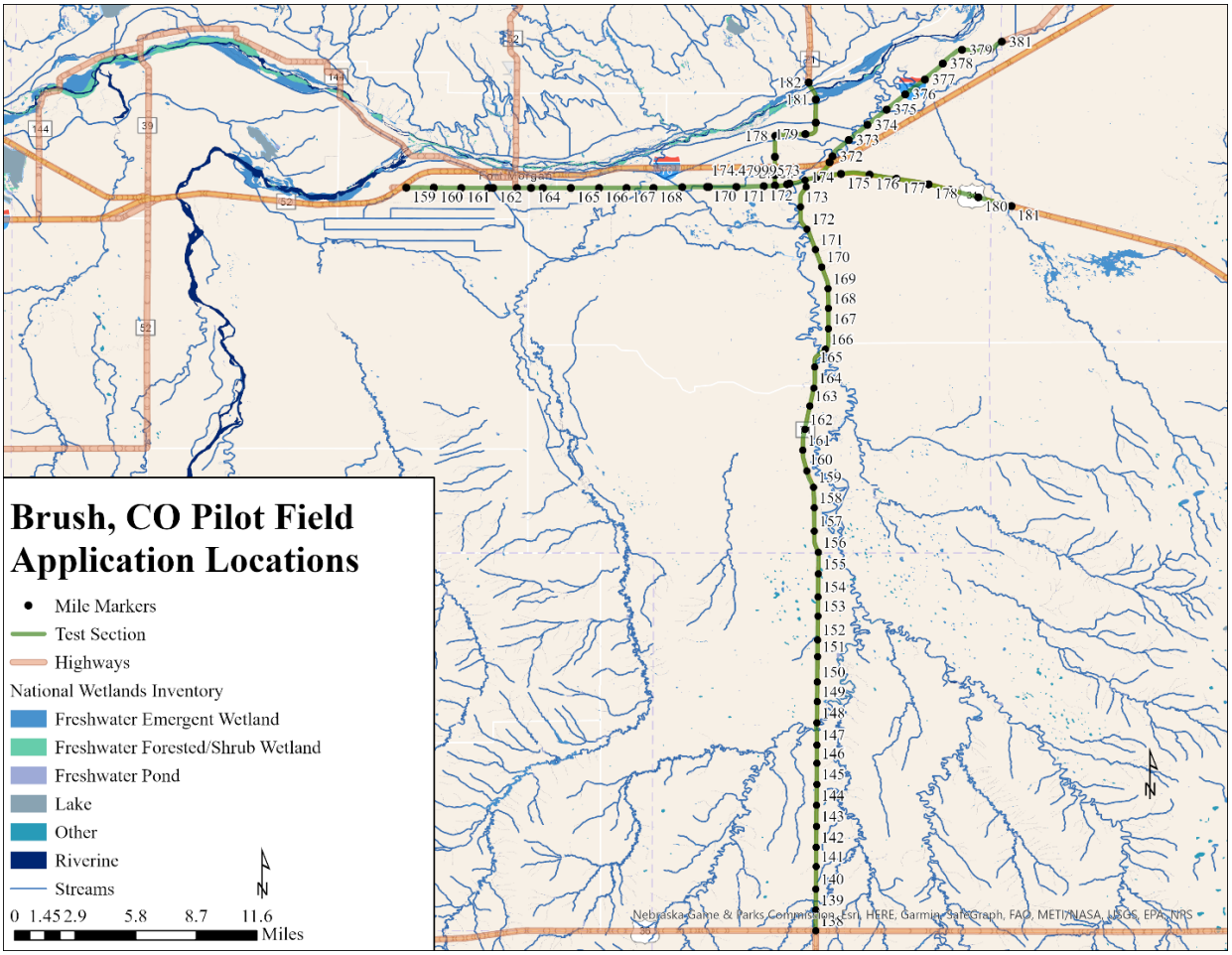

Figure 1. Map of approved pre-wet field trial locations near Brush, CO.

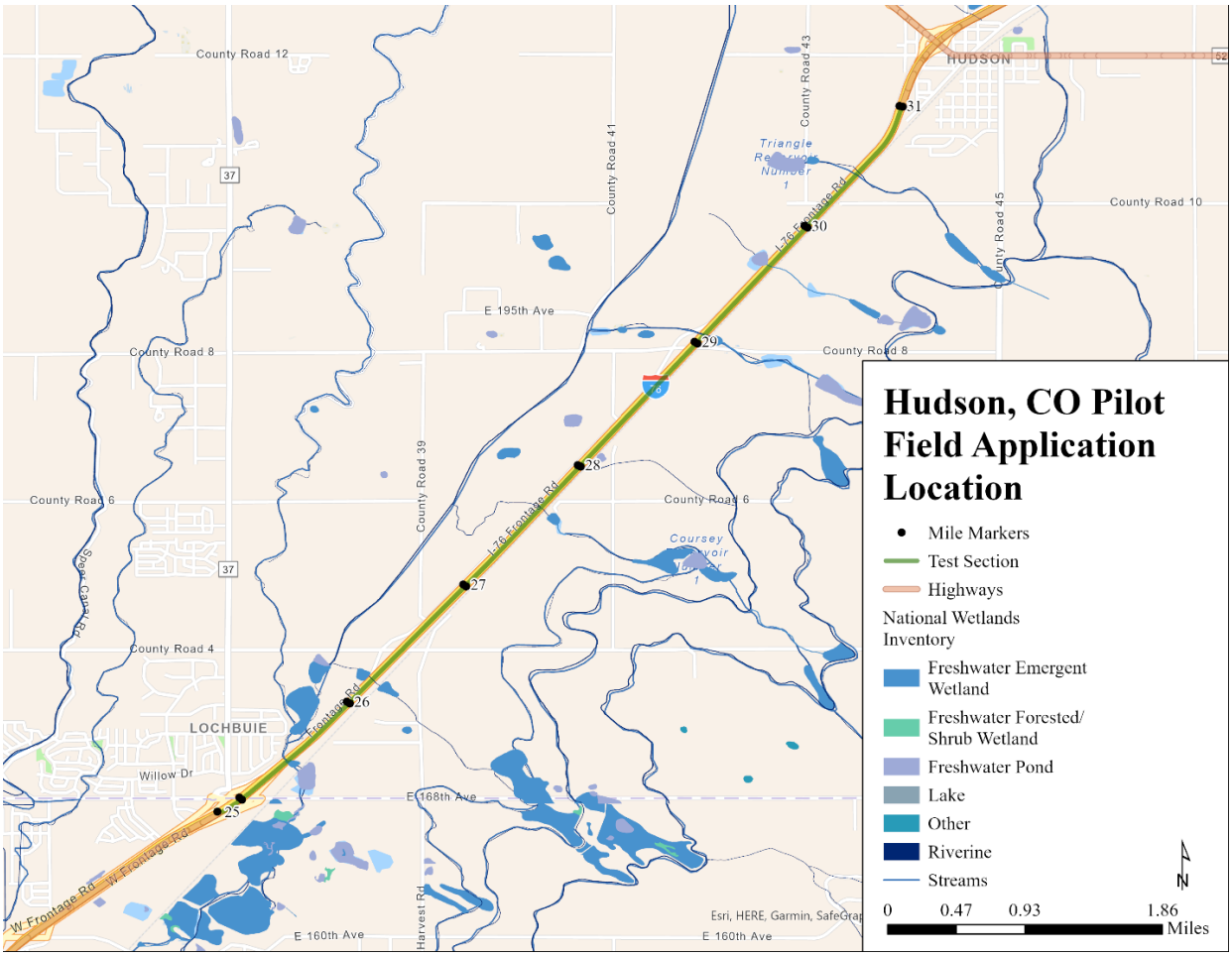

Figure 2. Map of approved pre-wet field trial locations near Hudson, CO.

The two field trial locations were chosen by CDOT due to proximity to the Leprino Foods facility, located in Fort Morgan, CO, where the LCB is stored and the CDOTs facilities willing to participate in the field trials.

Note that the distance to the Fort Morgan Leprino Foods facility is approximately 12 miles from the Brush, CO DOT facility, or 24 miles roundtrip, and over 50 miles from the Hudson, CO DOT facility, or over 100 miles round trip.

Pre-wet Application Guidelines

Based on CDOT guidelines and the approved CDPHE beneficial use permit, LCB was approved for application only along the routes shown in Figure 1 and Figure 2 as a pre-wetting agent, or a liquid added to solid material, rock salt, or sand-salt, prior to application on the roadway, at a rate of 8 gallons per ton. The maintenance crews participating in the field trials were encouraged to not deviate from normal practices and procedures and apply the LCB pre-wet material in the circumstances and conditions under which the solid or pre-wet material would normally be applied.

Prior to the start of field trials and any LCB pick up, it was stressed to the CDOT crews that the LCB should only be used in freshly cleaned out equipment, tanks, lines, filters, etc. It was also stressed that any residual material in the tank, lines, filters, etc. could cause clogging.

Field Tests

On March 16, 2022, the Hudson, CO garage picked up 900 gallons of LCB. This product was inadvertently applied directly to the road along I-76 between MM 25 – 38 at a rate of 30 gallons per lane mile (gal/l-m) at 2:00 P.M. MT with an air temperature of 57°F. The following morning at 4:00 A.M. a snow and rain event began with air temperature around 32°F. The Hudson crew noted a slight difference in the I-76 frontage road that was treated and the adjacent untreated Hwy 52. It is likely that the rain and wet snow diluted the LCB on the road, limiting its effectiveness. Following this application, it was reiterated to the Hudson, CO crew that the CDPHE benefit use permit terms only allowed for LCB to be applied as a pre-wetting agent at about 8 gal/ton to solid material.

On November 3, 2022, the Brush, CO crew picked up LCB picked up from the Leprino Foods plant in Fort Morgan, CO. The intention was to apply the pre-wet on November 4, 2022, when winter weather was forecasted to impact roads in their area. On November 7, 2022, it was found that the flow meter and nozzles of the liquid application system on the plow were clogged with an “off-white thick scum” (Figure 3). On November 8, 2022, the LCB was unloaded, and the screen filter removed for cleaning. White salt crystals were found clogging the screen filter (Figure 4). The Brush, CO maintenance crew noted that the tank in which the LCB was stored was drained two days after the storm and was then in the shop and required cleaning of all lines, nozzles, and screens/filters.

Figure 3. Off-white thick scum that clogged the flow meter and nozzles of the liquid application system.

Figure 4. Presumed rock salt crystals, found in the screen filter from the liquid application system.

Challenges identified in the pickup included:

1. Ensuring that the tanks used to pick up the LCB material were cleaned and devoid of any prior $MgCl_2$ based deicing materials (liquid or solid), and that the lines, screens and filters, and nozzles were flushed with water prior to pick up and use.
2. The frustration of being required to clean the truck tanks, lines, screens and filters, and nozzles mid-winter due to a test project.
3. Communication between the DOT shops dissuaded the Hudson, CO shop from picking up and testing the LCB because of the issues encountered in Brush, CO.
4. The distance from the DOT shops to the Leprino Foods facility required significant travel for pickup of LCB. This added extra planning, and travel time to and from the facility.

The second LCB pick up occurred on February 28, 2023, by the Hudson, CO facility. They picked up 200 gallons of LCB in saddle tanks on their spreader truck. At pick up, it was noted by present Leprino Foods staff that the CDOT tank had approximately 150 gallons of liquid already in it prior to pick up. They noted this to the driver and the liquid was described to them as brine water. The Leprino Foods staff noted that the tank was a little foamy after loading. Note that the Hudson pick up crew stated that the tanks were cleaned with water prior to the pickup. The Hudson crew attempted to apply the LCB as a pre-wet and it clogged the filters on the truck (Figure 5 and Figure 6). They had another chance to use the LCB for pre-wetting, but solid salt was found at the bottom of the tank (Figure 7 and Figure 8) and the application attempt did not occur.

Figure 5. Truck filter clogged with solid salt crystals.

Figure 6. Screen filter clogged with salt crystals.

Figure 7. Tank with solid salt precipitated out at the bottom of the tank.

Figure 8. Storage tank with solid salt precipitated at bottom.

Challenges identified in the pick up included:

1. There was a discrepancy in description at the time of pick up between the CDOT Hudson crew and Leprino Foods staff. One indicated that tanks already had liquid in them at the time of pick, and other indicated the tanks had been flushed prior to pick up.
2. The frustration of being required to clean the truck tanks, lines, screens and filters, and nozzles mid-winter due to a test project.

Field Trial Results

The field trials for LCB as a pre-wetting agent did not yield good results. Many challenges occurred including clogging of tanks, lines, filters, and pumps, which caused additional cleaning and down time of critical winter maintenance equipment.

At the Fort Morgan Leprino Foods facility, the LCB is stored outside in an open-air tank (Figure 9). Over time, the stored LCB became concentrated due to evaporation. This elevated the salt concentration to the point that, without agitation, salt would precipitate out of the solution. The initial LCB salt concentration was about 13% but after time in the outdoor storage tank the salt concentration increased to over 23% (Table 1). While, in theory, the rise in salt concentration from 13% to 23% is ideal, as salt brine applied on roads is made at 23.3%, the concentrated LCB from evaporation created a situation where the salt could not remain in solution and precipitated out, thus clogging the filters and equipment (Figure 4, Figure 5, Figure 6, Figure 7, Figure 8).

Figure 9. LCB storage tank at Leprino Foods in Fort Morgan, CO.

Another concern was the sludge-like substance that formed after the first Brush, CO pick up (Figure 3). A bench top study found that adding as little as 6% of the LCB to the magnesium chloride ($MgCl_2$) liquid deicer (Apex) used by CDOT caused the formation of semi-solid gelatinous material in the mixed materials. While the initial CDOT staff training on implementation of the field trials stressed that tanks, lines, filters, etc. needed to be flushed and cleaned prior to LCB pick up and use, the reality is that compliance was challenging to enforce. The resulting clogging of tanks, lines, and filters lead in part to the failure of this effort. It is possible some residual Apex remained in the tanks, lines, etc. Leprino Foods ensured they would put additional filtration on the storage tank outlet and move the outlet line from the bottom of the tank to instead pull LCB from the middle of tank. The was done in time for the second pick up by the Brush, CO DOT. This was not the case for the first pick up.

Cost – Benefit of using LCB

Costs

While the field trials were not successful, an effort to assess the costs and potential benefits of using LCB to pre-wet was conducted.

The Hudson, CO pick up cost was $320 for 900 gallons of LCB. For the Hudson Garage, cost is measured in hours, and 2.5 hours were charged for the work order for personnel hours and benefits ($157.76) and an equipment fee of $162.15 was included as well.

CDOT would typically use Ice Slicer pre-wet with Apex at a cost of $2,428 for a fully loaded truck (12 tons IceSlicer + 800 gallons Apex). Standard CDOT practice is to apply solids (Ice Slicer) at 150 pounds per lane mile (lbs/l-m) and, if pre-wet, liquid is added at 8 gallons per ton.

Costs in 2023 US Dollars:

- Personnel hourly rate with benefits: $63.07
- Equipment hourly rate: $162.15
- Ice Slicer (NaCl rock salt): $133 per ton
- Apex (liquid $MgCl_2$): $1.04 per gallon

Costs to use LBC as pre-wet	Material/Cost Savings	Savings from using LCB
Pick up cost: $320	800 gallons of Apex = $832	$832 - $320 = **$512 per truck**

The Brush, CO pickup of LCB took about 3 hours. Estimated cost for one LCB pickup is $351 assuming the same personnel and equipment costs as Hudson, CO (or 3 hours of personnel time and one hour of equipment time). Brush, CO was not able to successfully apply LCB due to clogging issues. For both loads of LCB picked up by Bush, CO, they spent 5 hours taking the pump apart to cleaning it, which cost $437.00 for the mechanic's time.

Costs to use LCB as pre-wet	Material/Cost Saving	Saving form using LCB
Pick up cost: $351	300 gallons of Apex = $312	$156 – $351 = **$ -39 per truck**
Pickup + Cleaning costs: $788	300 gallons of Apex = $312	$312 - $788 = **$ -476 per truck**

Note that cost saving shown above for Brush, CO for the pickup and cleaning cost do not account for the amount of time the equipment was down due to cleaning, which could be estimated at 5 hours at $162.15 per hour, or $810.75.

Overall, the cost analysis shows that if LCB is picked up in large quantities and used to offset a large volume of Apex (or equivalent liquid deicing product), and if the LCB can be successfully picked up and applied as a pre-wetting agent, there is potential cost saving for CDOT. The challenge of the LCB clogging the tank, lines, filters, and pumps was the primary roadblock preventing successful implementation of this project.

Other Benefits

One of the greatest benefits of using LCB is Leprino Foods provides it free of charge. Under perfect circumstances, the only cost to CDOT would be the personnel and equipment hours associated with pick up. An additional benefit is that Leprino Foods and Colorado DOT both bring salt into the state of Colorado from other sources outside of the state and both contribute salt to the environment. If LCB were to be used by CDOT in place of brine or Apex, this would reduce the amount of salt brought into Colorado and put into the environment.

Task 2 Leprino Liquid Anti-icer

A second objective of this project was to support Leprino Foods in the development and testing of an improved Leprino Cheese Brine (improved LCB), through guidance, testing, and evaluation of results. The goals were to 1) determine if an improved LCB could be made that would pass Colorado State environmental standards, and 2) assess the performance of the improved LCB as an anti-icing product, a liquid deicer applied directly to the roadway, and to test its relative performance to liquid deicing products used by CDOT of a similar category[1]. If the improved LCB proved to be a viable option, then a benefit use permit would be sought and, if granted, field trials would be conducted.

This section provides a detailed description of the effort put forth in this task.

Creating the Improved LCB

The need to create an improved LCB is based on the elevated phosphorus, and other elements, present in LCB as it leaves the factory, which prevents the LCB from passing Colorado State environmental standards. For the purpose of this project, beneficial use permits are required prior to application of any experimental deicers in the state of Colorado.

Preliminary work by Leprino Foods determined that iron, in the form of ferric chloride, can be used to remove phosphorus from the LCB. Phosphorus was found in LCB at concentrations greater the Colorado state environmental specification limit of 25 mg/L. Multiple samples of LCB were collected and tested for total phosphorus: as it leaves the factory (LCB (raw, ultrafiltered (UF))), the LCB (raw, UF) treated with iron (Improved LCB), the LCB from the outdoor open air storage tank (Storage tank LCB), and the LCB from the outdoor open air storage tank (Storage tank LCB) treated with iron (Storage tank improved LCB) (Table 1). Based on the laboratory data, the use of iron to remove phosphorus sufficiently decreased total phosphorus concentrations to meet the Colorado state environmental standard.

[1] The improved LCB should be compared to similar products, complex chloride salt brines with agriculturally derived additives or NaCl (salt brine).

Table 1. Leprino Cheese Brine samples and total phosphorus concentrations (mg/L).

LCB Sample Description	Total Phosphorus (P) (mg/L)	Sodium Chloride (NaCl) (mg/L)	Cyanide (CN) (mg/L)
LCB (raw, filtered)	548	19.7	0.94
Improved LCB	18	20.5	0.20
Storage tank LCB	759	23.4	0.27
Storage tank Improved LCB	ND (non-detect)	24.2	ND (non-detect)

Based on these results, an application for a beneficial use permit was submitted to CDPHE for the use of improved LCB as an anti-icing liquid. The application was reviewed, and meetings were held between CDPHE, Leprino Foods, and the research team to discuss the permit application. It was noted by CDPHE that the phosphorus removal was successful in the bench top test but had not been demonstrated using the scaled-up design (See Appendix C – Proposed treatment design to make Improved LCB). In order for the beneficial use permit to be granted, samples from the scaled-up design need to show similar results. The scaled-up design was under development by Leprino Foods, but they were waiting to make any large financial investments in the process until a permit was granted.

Additionally, other elements, such as cyanide, were identified by CDPHE in both the LCB and improved LCB at elevated concentrations that would need to be addressed. The water quality regulation for cyanide in Colorado ranges from 0.005 – 0.2 mg/L (free cyanide, acute exposure; State of Colorado, 2023). Cyanide is present at very low concentration in the salt used to brine the cheese and is used as an anti-caking agent in rock salt. The LCB and improved LCB samples had cyanide concentrations shown in Table 1. Leprino Foods noted that cyanide is not present at concentration of concern in the cheese produced. Based on this information, it appears that the cyanide is concentrating in the brine as it moves through the facility and in storage.

At this point in the project, Leprino Foods terminated their effort to create an improved LCB for the following reasons:

- The effort required to remove all elements of concern necessary to gain a benefit use permit was beyond what Leprino Foods could invest.
- Cost and time required to build the scaled design for phosphorus removal.
- Complications experienced with CDOT in the use of LCB as a pre-wetting agent gave Leprino Foods a lack of confidence in the investment.

As of June 2023, Leprino Foods noted that they will no longer continue to work to improve LCB. Work on this task was terminated by the research team and CDOT was notified.

Challenges

While it initially appeared to be a straightforward process to create the improved LCB and to be granted a beneficial use permit for CDOTs application as an anti-icer, creating the improved LCB became more complicated due other elements of concern beyond phosphorus.

Conclusions

There is potential for LBC to be a viable option for immediate use as a pre-wetting agent, but the following efforts will need to be made to provide consistency in the product and procedures: 1) quality control of LCB by Leprino Foods, and 2) tanks and application equipment cleaning by CDOT. Currently the LCB is pumped from the facility into an outdoor open air storage tank. The LCB stored in the outdoor open-air tank has had significant evaporation over time, concentrating the contents. This created a super saturated LCB product, specifically for NaCl, causing salt crystals to precipitate out of solution and clog tanks, lines, filters, and pumps. Ideally, the LCBs NaCl concentration would be consistent overtime. To ensure this, the LCB would need to be used as it leaves the facility or the LCB needs to be stored in covered and sealed storage tanks prior to pick up. Additional work is needed to ensure consistency in the LCB over time including considerations of storage, filtration as it leaves the storage tanks, and testing to ensure consistency.

A second issue that occurred was the clogging of tanks, lines, filters, spray nozzles, and pumps after pick-up of LCB and during attempts to apply LCB as a pre-wet. In preliminary discussions with CDOT staff, they were made aware of the fact that they needed to use clean tanks, lines, etc. to prevent cross contamination with other deicing products. Unfortunately, this occurred and created issues for CDOT to clean up. While the CDOT staff stated the tanks were flushed out and cleaned prior to LCB pick up, it is likely that some amount of material remained in the tanks and caused the clogging of the lines and filters.

Ultimately, these issues prevented the pre-wetting field trials from occurring a sufficient number of times during the two winter seasons for a detailed analysis of its effectiveness.

Viable future uses of LCB as a liquid anti-icier would require the scaling up and refinement of the removal of elements so that the product can pass state environmental guidelines. The bench top study completed by Leprino Foods showed that it is possible to remove phosphorus from the LCB and they provided plans for a scaled-up system to produce improved LCB. Given the effort required to reach this point, Leprino Foods decided to step away from committing more resources to this effort. The amount of effort required to reduce elemental concentrations in the LCB low enough to allow it to pass Colorado state environmental standards was beyond what Leprino Foods could invest in the project. Leprino Foods committed significant resources in terms of employee hours, storage of LCB, and financial investment in tanks and design of the improved LCB system. Multiple bench top studies failed to produce an improved LCB sample that could pass all Colorado state environmental standards. Both Leprino Foods and the research team feel it is possible to create an improved LCB for direct liquid application in the state of Colorado, but additional work is required for this to occur.

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Appendix A – CDOT Leprino Cheese Brine Field Trial Plan

CDOT Leprino Cheese Brine Field Trial

Product:	Leprino Cheese Brine (LCB)
Testing Locations:	Hudson and Brush, Colorado
Date:	January – April 2022

Introduction

As a part of the active research project with Colorado DOT titled *Side-by-side comparison of agriculturally-based deicing additives*, Leprino cheese brine was identified as a potential source of salt brine for use in winter maintenance operations. Preliminary testing has determined that the LCB is a complex brine made primarily of sodium chloride (NaCl) and functions similarly to traditional salt brines used in winter maintenance operations. The LCB was found to provide mild corrosion protection, compared to salt brine alone, due to additives gained in the cheese brining process.

The Leprino Foods Fort Morgan facility produces 6,000-8,000 gallons of cheese brine each month. Once Leprino is done with the brine, they blend it with their influent raw wastewater at a low dilution rate so that the treated wastewater, from the on-sight water treatment facility, has acceptable total dissolved solids (TDS) and conductivity (read: chloride concentration) levels to allow for direct discharge to the rivers.

Instead of disposing of the LCB, Leprino is seeking a beneficial use permit from the Colorado Department of Public Health and Environment (CDPHE) to allow for the use of LCB as a deicer in winter maintenance operations. Benefits from the reuse of LCB can be seen by both parties, such as:

- Leprino
    - Reduced environmental and carbon footprint of operations.

- CDOT
    - Free salt brine with mild corrosion protection
    - Salt brine availability year round
    - Reduced water use to make salt brine
    - Reduced cost from the purchase of deicing materials
    - Reduced environmental and carbon footprint of operations

Historically, Leprino cheese brine was used for dust control but that is no longer the case. By using the cheese brine that already exists in Colorado from the Leprino facility there will be *a net reduction of salts making it into the States watershed*, as less salt will need to be purchased and brought into the state by CDOT for use in winter maintenance operations.

Test Plan Specifics

Roadway Environment

The following test sections have been identified to for field trials of LCB:

- US 34 from mile marker (MM) 159-180.7, Hwy 71 MM 175.5-181.4, and Hwy 6 MM 371 to 380.5 (APPROVED)
- I-76 frontage road from MM 25 to MM 31, (APPROVED)
- Colorado Springs - along Hwy 21, Hwy 24 east, Hwy 94 (NOT APPROVED)

These locations were selected due in part to proximity to the Fort Morgan Leprino facility that is currently storing the LCB, as well as interest on the part of the maintenance managers to participate in this effort.

As part of the CDPHE permit process, for each road segment where LCB will be used, environmentally sensitive areas including water ways, protected area, etc., will be identified, and application of LCB will be avoided if possible.

Winter Events

Application of the LCB will occur at the maintenance facilities' discretion following normal protocols. Any and all winter conditions can and should be targeted in which normal deicer application would occur. No deviation from normal practices should occur.

Testing Methods & Equipment

LCB should be applied as a pre-wetting agent, a liquid added to solid material prior to application. LCB may be added to rock salt or sand-salt at normally prescribed rates for CDOT, or approximately 8 gallons per ton.

Test Material

As noted above in the introduction, Leprino cheese brine (LCB) is a complex chloride composed primarily of sodium chloride (NaCl) with small amounts of magnesium chloride ($MgCl_2$) and calcium chloride ($CaCl_2$). The LCB has a 13-16% NaCl concentration and is stored in large tanks at the Fort Morgan Leprino facility.

LCB will be picked up using DOT trucks at each driver's discretion. Communication between CDOT and Leprino Foods for LCB pick up should be done via phone or email with:

Troy Gettman
Email: tgettman@leprinofoods.com
Phone: (970) 542-4256

Jim Volk
Email: jvolk@leprinofoods.com
Phone: (970) 867-9351

Data Collection Tools
Data will be collected on the following metrics:

- Logistics
    - Ease of pick up at the Leprino facility
    - Ease of use in normal winter maintenance operations
    - Does having a designated truck/tank for LCB work with your normal operations? (*Note that LCB cannot be mixed with magnesium chloride ($MgCl_2$) brines as it can cause clogging issues. A primary liquid used by CDOT is Apex, a magnesium chloride-based brine.)
    - Have you modified any logistics with getting, storing, or applying LCB since the start of the field trial?
    - Identify any challenges with logistics
- Functionality
    - How did the product perform?
    - Did it freeze in the tanks? Performance in storage?
    - Did any lines or equipment clog up or not work as well? (*Note that LCB cannot be mixed with magnesium chloride ($MgCl_2$) brines as it can cause clogging issues. A primary liquid used by CDOT is Apex, a magnesium chloride-based brine.)
    - Have you modified the application or use of LCB since the start of the field trial?
    - Identify any challenges in performance or functionality
- Costs and Benefits
    - Person and equipment hours and costs incurred from the pickup and storage of LCB by CDOT.
    - Amount of LCB applied in each location
    - Amount of normal deicing product saved by using LCB, and the costs (re: savings) associated with this.
    - Any additional costs, savings, or benefits identified?

This information will be captured through monthly conversations with the maintenance managers from Brush and Hudson CDOT facilities and with Leprino Foods. An end of the season conversation will be used to capture cost information and allow the maintenance manager to provide additional input.

Appendix B - CDOT Data Collection Plan - Leprino Cheese Brine Field Trials

The following questions were developed to guide responses from the CDOT users of the LCB following field application.

Logistics

- Ease of pick up at the Leprino facility
- Ease of use in normal winter maintenance operations
- Does having a designated truck/tank for LCB work with your normal operations? (*Note that LCB cannot be mixed with magnesium chloride (MgCl2) brines as it can cause clogging issues. A primary liquid used by CDOT is Apex, a magnesium chloride-based brine.)
- Have you modified any logistics with getting, storing, or applying LCB since the start of the field trial?
- Identify any challenges with logistics

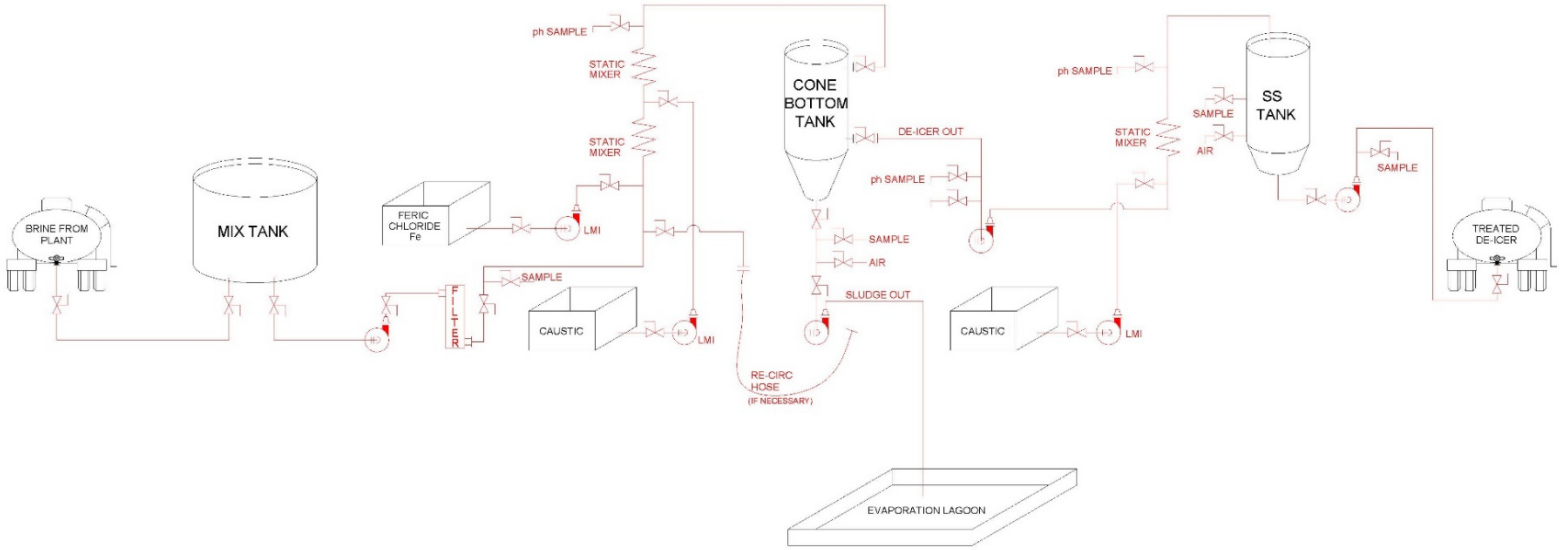
Functionality

- How did the product perform?
- Did it freeze in the tanks? Performance in storage?
- Did any lines or equipment clog up or not work as well? (*Note that LCB cannot be mixed with magnesium chloride (MgCl2) brines as it can cause clogging issues. A primary liquid used by CDOT is Apex, a magnesium chloride-based brine.)
- Have you modified the application or use of LCB since the start of the field trial?
- Identify any challenges in performance or functionality

Costs and Benefits

- Person and equipment hours and costs incurred from the pickup and storage of LCB by CDOT.
- Amount of LCB applied in each location
- Amount of normal deicing product saved by using LCB, and the costs (re: savings) associated with this.
- Any additional costs, savings, or benefits identified?

Appendix C – Proposed treatment design to make Improved LCB



DE-ICE SYSTEM BLOCK FLOW

REV.	DATE	DESCRIPTION	BY

AS SET OUT IN THE CONFIDENTIALITY AGREEMENT EXECUTED BY VENDOR, VENDOR ACKNOWLEDGES AND AGREES THAT THIS DRAWING AND ALL ACCOMPANYING INFORMATION ARE CONFIDENTIAL AND PROPRIETARY TO LEPRINO, WHICH MAY NOT BE DISCLOSED TO A THIRD PARTY FOR ANY PURPOSE. BY ACCEPTING THIS DRAWING, THE VENDOR ASSUMES RESPONSIBILITY FOR THE ACCURACY OF ITS BID AND WORK PRODUCT AS RELATED TO THE DRAWING. VENDOR MUST INFORM LEPRINO IN WRITING IF IT MAKES ANY ASSUMPTIONS BASED ON THE DRAWINGS THAT FORM THE BASIS FOR ITS BID. THE VENDOR ACCEPTS RESPONSIBILITY FOR DOCUMENTING AND INFORMING LEPRINO IN WRITING OF ANY WORK-PRODUCT DISCREPANCY THAT WILL DEVIATE FROM THE ACTUAL DRAWING OR SPECIFICATION.

Leprino Foods

DATA CODE: PROJECT	LOCATION: FORT MORGAN	TYP: BLOCK FLOW	TAG: GAXX	NO.: 220920	
W.O. DRAWING: ---		AR NO.: -	SCOPE: WASTE WATER		
DESIGNED: CKW	9/20/22	SHEET DESCRIPTION & NO.: BLOCK FLOW DIAGRAM		SHEET: 1	
APPROVED: JMV	9/20/22				
DRAWING NO.: P-FTM-BFGAXX-220920-WW DE-ICE		PROJECT: WASTEWATER DE-ICE SYSTEM		REV.: 0	

ARCH-D 18 X 24

FILE PATH: S:\CAD\Chuck\Dept MAINTENENCE\WW De-Icer Flow Plan.dwg PLOT DATE: September 20, 2022