Extending The Shelf Life Of Food & Beverages

PRESCOUTER

Extending the shelf life of food and beverages is, now more than ever, far from an impossible dream.

Approximately 1.3 billion tons of food is lost or wasted globally at a cost of nearly $1 trillion. Towards reducing food waste across the supply chain, we highlight some of the newest and most promising technologies in development to prolong the shelf life of various foods and beverages.

Food preservation is a concern not just for industry-related clients, but for consumers as well.
The research in this area is especially interesting, as it's an industry that really listens to the consumer base. This is evidenced by a push toward food derivatives for novel packaging and the desire to extend the lifetime of purchased food products to reduce food waste.

One major trend seen throughout the research is a move toward more food- and plant-based additives and packaging, a "natural" approach as it comes across to consumers. From superior coating materials to novel additives to putting a new spin on older technologies, here are 21 innovative solutions focused on extending the shelf life of food and beverages.

Whether packaging producers are sourcing new additives, utilizing old technologies, or turning to their gardens to improve shelf life and food/beverage quality, the industry is continually pressing forward in innovative ways.

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Novel Packaging Technologies

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One major trend seen here is a move toward more food- and plant-based additives and packaging, a “natural” approach as it comes across to consumers.

NanoPack, university researchers, and Apeel are all using plant/food based components for *superior coating materials*.

Other companies/groups such as Stepac and Seawell are utilizing *novel additives* to slow food degradation.

In contrast to the former two ideas, some packages are utilizing older technology with a new spin. For example, Advanta is utilizing *modified atmosphere packaging* (MAP) within a new container so that chicken can be cooked directly in the package and the introduction of contaminants is avoided entirely.

9 Novel Packaging Technologies for Extending Shelf Life

The Major Features of Each Technology

Technology	Company / Organization	Phase	Food Use Approval	Type	Year
Halloysite Nanotubes	nanopack	Research	✓	Antimicrobial packaging	**2017**
Nanosilica Powder		Research		Potato sprouting inhibitor	**2018**
Poultry Tray	ADVANTA	Product	✓	New foil packaging solution	**2018**
Resealable Lidding Film	StePac	Product	✓	Humidity-control packaging	**2018**
Mango Peel	BARC	Research		Antimicrobial packaging	**2017**
Seawell Absorbent	MAXWELL CHASE A CSP TECHNOLOGIES Company	Prototype	✓	Moisture absorbent packaging	**2018**
Graphene Oxide		Prototype		Preservative packaging	**2018**
Apeel's Edible Coating	APEEL SCIENCES	Product	✓	Invisible coating	**2016**
Nanoselenium Packaging	Universidad Zaragoza	Prototype	✓	Multilayer packaging	**2018**

Essential oils in biocompatible nanopackaging

Some plant oils have antimicrobial properties, and releasing the active ingredient in essential oils into packaged food products could help extend their shelf life. NanoPack, an EU-funded joint research project, is developing antimicrobial packaging made of nanomaterials that can be infused with these essential oils. Begun on Jan. 1, 2017, the project is expected to be completed in 2020.

At a glance

Type	Antimicrobial packaging
Year	2017
Key Feature	Halloysite nanotubes infused with antimicrobial essential oils
Current Application	Bread
Applicability	Any type of packaged food
Main Limitation	Possibly cost

Technology

NanoPack uses halloysite nanotubes (HNTs), which are hollow clay mineral fibers composed of aluminum and silicon atoms. HNT absorbs ethylene produced by fresh food products, which acts as an aging hormone that ripens food items. The essential oils infused into the HNT packaging act as antimicrobial agents to eliminate microbes. The US FDA, and the European Council who funded the NanoPack project stated that HNTs cannot migrate from food packaging into food items themselves, which deems them safe for use as food packaging.

Figure: NanoPack active packaging extends bread shelf life by 3 weeks. A first round of antimicrobial efficacy tests proved NanoPack film's ability to inhibit mold growth on food-additive free bread. The bread that was inoculated with mold spores and packed with NanoPack innovative film insert had no mold growing in the area exposed to the film for up to 27 days post packaging.

Essential oils in biocompatible nanopackaging

Benefits

- HNTs and essential oils occur abundantly in nature, which means they are easy to obtain and are biocompatible
- HNTs have high mechanical strength
- Incorporating essential oils into the packaging would lend it antimicrobial properties
- Adding essential oils contributes thermal stability which would allow HNT to be formed into various types of food packaging using existing techniques

Drawbacks

- Essential oils have high volatility, so their release rate into foods may not be consistent at longer time periods
- Duration of protection afforded has not been systematically studied on many food items (studies have been conducted on microbes extracted from food and on a few food items such as bread). So, more research is needed for widespread adoption

Recent Developments & News

On Nov 14, 2019, NanoPack revealed the results of its EU-funded project proving that its novel film has the ability to extend the shelf life of bread by 3 weeks, cherries by 40%, and yellow cheese by 50%.

NanoPack's antimicrobial packaging solution can potentially replace conventional packaging films. The biggest bottleneck may be cost and development time. As the project is still in the research stage, a cost-effective solution could be developed.

References

1. https://www.nanopack.eu
2. http://ec.europa.eu/research/infocentre/article_en.cfm?&artid=49196&caller=other
3. https://doi.org/10.1016/j.carbpol.2016.07.041
4. https://doi.org/10.1002/app.42771
5. https://www.prnewswire.com/news-releases/nanopacks-active-food-packaging-shows-impressive-results-in-extending-food-shelf-life-300958387.html

Nanosilica to prevent potato sprouting

Potatoes are a major food source in many regions, but they can sprout during storage, causing them to produce α-solanine, which is toxic to humans. Current methods for slowing the rate of potato sprouting include cold storage, irradiation, and chemical methods such as desiccation and organic chemicals applied to the surface. Researchers at the Chinese Academy of Sciences are developing a new method that uses hydrophobic nanosilica powder obtained through modifying nanosilica with amino silicon oil (ASO).

At a glance

Type	Potato sprouting inhibitor
Year	2018
Key Feature	Surface treatment, nonpenetrative
Current Application	Potatoes
Applicability	n/a
Main Limitation	Nanosilica waste runoff into sewage systems

Technology

To treat the potatoes, they are immersed in a solution of hydrophobic nanosilica powder dissolved in ethanol. It was determined that higher concentrations of hydrophobic nanosilica powder in the solution are better able to inhibiting sprouting.

To show that the nanosilica did not penetrate the potato skin, researchers looked at its concentration present on the outer surface of the potato skin before and after hand-washing with water as well as the amount present on the inner surfaces of the potato skin and showed that none of the nanosilica was able to penetrate the skin.

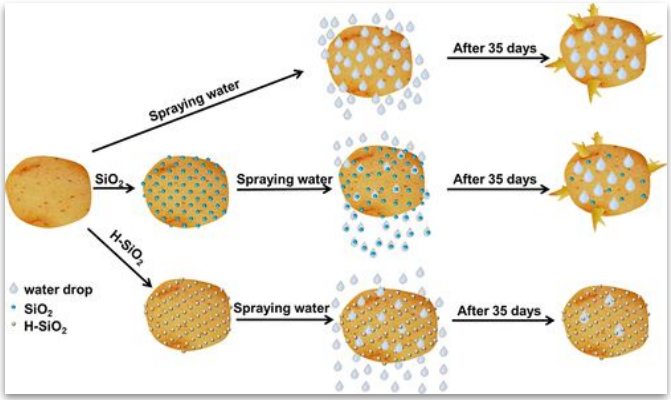


Figure: Hydrophobic nanosilica was fabricated to efficiently inhibit potato sprouting, which has a tremendous application potential for durable storage of potatoes.

Nanosilica to prevent potato sprouting

Benefits

- Nanosilica does not penetrate into potato skin, making treated potatoes safe for consumption after hand-washing with water
- Treated potatoes are still able to germinate when used as seeds in soil
- Nutritional values of treated potatoes were not significantly influenced by treatment
- Treatment cost was calculated to about US $5/ton of potatoes, making it a cheap treatment option

Drawbacks

- Consumers may be hesitant to consume a product that has been immersed in nanosilica
- Application of this method to other food products has not been investigated
- Nanosilica waste after potatoes have been hand-washed may cause problems in the sewage system

In UK households, 5.8 million potatoes are thrown away daily, at an annual cost of about 295 million USD. This research proves to be a cost-effective way to extend the shelf life of potatoes and significantly reduce food waste.

References
1. https://pubs.acs.org/doi/abs/10.1021/acssuschemeng.8b01860
2. https://www.theguardian.com/environment/2017/nov/08/nearly-half-of-all-fresh-potatoes-thrown-away-daily-by-uk-households

A combination of skin pack aluminum tray and film

Advanta, a global packaging supplier company, has introduced a unique combination of chicken-shaped aluminum poultry tray and film to extend the shelf life of poultry products. The skin pack is touted by the company as an excellent alternative to the standard modified atmosphere packaging (MAP).

At a glance

Type	New foil packaging solution
Year	2018
Key Feature	Alternative to MAP, plastic trays, easy to use, thermally stable, eliminates the need for using preservatives in poultry
Current Application	Chicken
Applicability	Poultry products
Main Limitation	Does not insure against spoilage, packaging equipment needs proper cleaning and sanitization

Technology

The packaging combines the convenience of a chicken-shaped aluminum foil tray and shelf life extension to reduce food waste. The poultry is vacuum-packaged in the foil tray, which gets rid of the oxygen and eliminates spoilage-causing microbes, as they require oxygen to grow. The low-oxygen and high-CO2 environment significantly reduces the growth of microorganisms, allowing an increased shelf life. The packaging can enhance the shelf life of refrigerated poultry, sometimes by up to 300%.

Many customers do not want to touch an uncooked chicken. Advanta's secure packaging lets customers easily peel back the plastic film surrounding the poultry to reveal the whole chicken in a foil tray, ready to cook. Therefore, the chicken can be put straight in the oven without any complication. The new skin pack aluminum tray can withstand temperatures from -40°C to 400°C.

A combination of skin pack aluminum tray and film

Benefits

- The packaging eliminates the need of using preservatives
- It is robust, shatterproof while frozen and rigid in an oven
- The tray is 100% recyclable and eco-friendly compared to plastic tray alternatives

Drawbacks

- Vacuum products do not insure against spoilage
- Vacuum packaging equipment needs to be cleaned and sanitized regularly

Packaging will always determine a customer's interest in the product regardless of the quality or taste. A tray that allows poultry to be cooked directly in the packaging makes it even more attractive. With the consumption of poultry products on the rise, this packaging is unique and tailored for this purpose. The product has generated a lot of interest among retailers and manufacturers as it offers a longer shelf life with reduced supply-chain waste.

References

1. https://www.foodprocessing-technology.com/news/advanta-launches-new-packaging-solution-poultry/
2. https://www.poultryworld.net/Meat/Articles/2018/6/New-packaging-solution-for-US-poultry-industry-300704E/
3. http://www.packagingnews.com.au/food/a-chicken-skin-pack-that-fights-food-waste
4. http://www.vakuumverpacken.de/GB/fachberichte/all_you_need.pdf

Resealable lidding film

In recent years, the demand for high-quality produce has driven the development of innovative and low-cost packaging solutions. StePac Ltd. has partnered with Tadbik Ltd., Israel, to produce the next generation of modified atmosphere resealable lidding films. The technology was engineered to produce the combined effect of modified atmosphere (high CO_2 & low O_2), modified humidity (90-95%), and condensation control (release of excess moisture), and it has been used to ensure prolonged storage and shelf life of fresh cherries.

At a glance

Type	Modified atmosphere/humidity packaging
Year	2018
Key Feature	Condensation and film permeability control, quality preservation, low cost packaging
Current Application	Cherries and blueberries
Applicability	High-quality fruits and vegetables
Main Limitation	Not tested with other fruits or high-value produce yet

Technology

In collaboration with StePac, Tadbik generated a “Freshlid” laminated film. It is sealed to trays containing fresh produce and the upper layer can be repeatedly peeled back for reuse. The packaging design helps shelf life extension by slowing the process of respiration and aging while keeping humidity under check. The companies have worked together to design superior condensation control properties and film permeability to ensure optimal modified atmosphere conditions (MAP) for high-value fresh produce.

This Innovative fresh-produce packaging has been approved for extending the shelf life of cherries and will be marketed under the Xgo, a leading retail brand of StePac.

In a successful pilot study, Frutera San Fernando S.A., (FRUSERA), a market leader in the Chilean cherry export market, exported various refrigerated cherry containers sealed with Xgo resealable lidding film in China. The success of this project has encouraged FRUSERA to export sealed cherries to Chile. Cherry pickers and shippers have also expressed tremendous enthusiasm. Moreover, the blueberry industry is also interested in using this technology.

Resealable lidding film

Benefits

- Xgo resealable lidding film preserves the freshness and flavor of cherries to more than 35 days
- Consumers can savor cherries during extended home refrigerator life as the film ensures quality preservation.
- The seal maintains its attractive design through several uses

Drawbacks

- Shelf life extension of other food items has not been tested with resealable lids

Recent Developments & News

On Dec 2,2020, StePac was acquired by Nili Capital Partners, an Israeli private equity fund. StePac will form the nucleus of Nili's modified atmosphere packaging (MAP) platform, MAPfresh Holdings, Inc.

On Jan 19, 2021, San Diego-based produce distributor, Divine Flavor announced the adoption of StePac's XGo standing pouch for direct field-to-home refrigerator packaging of its Persian cucumbers for the US market.

References

1. http://foodindustryexecutive.com/2018/08/stepac-leads-responsible-supply-chain-with-innovative-packaging/
2. http://www.stepac.com/catalog
3. https://www.producebluebook.com/2021/01/19/divine-flavor-adopts-shelf-life-extending-packaging/
4. https://www.prnewswire.com/il/news-releases/stepac-acquisition-by-nili-capital-new-prospects-for-growth-301183725.html

Mango extract for packaging film

Addition of antimicrobial agents into polymers used to make packaging films for food is a common way to extend shelf life. Mango peels show both antioxidant and antibacterial activity because they contain phenolics such as mangniferin, quercetin, ellagic acid, kaempferol, and their related conjugates. Researchers from the Bhabha Atomic Research Center (BARC) have shown that these compounds can be extracted and incorporated into bio-based packaging made of a polyvinyl alcohol-cyclodextrin-gelatin composite film.

At a glance

Type	Antimicrobial packaging
Year	2017
Key Feature	Antibacterial, ethylene inhibition
Current Application	Poultry, fresh fruit
Applicability	Other proteins, produce
Main Limitation	Cost

Technology

The phenolics in mango peels can be extracted by sonication with aqueous ethanol before the extract is then added onto composite films. With the known antibacterial properties of the phenolics, they consistently reduce bacterial activity in food items. It was demonstrated that the addition of mango peel extract to packaging film extends the lifespan of minced chicken kept in a fridge by 10 days. The films have also been shown to slow down the rate of ethylene production which slows down the rate of ripening (and rotting) of fresh fruit products.

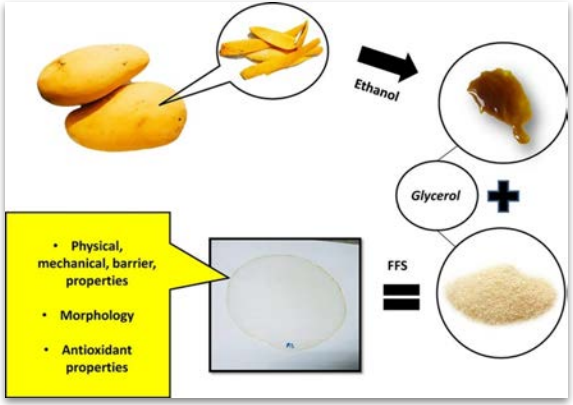


Figure: Graphical abstract from the article: Utilization of mango peel extracts on the biodegradable films for active packaging

Mango extract for packaging film

Benefits

- The film has improved UV-blocking properties and higher tensile strength
- The film does not affect gas balance of fruits when used to coat fresh fruit products
- The extract is derived from food products, so it is safe for food contact
- The film has higher hydrophobicity, which prevents water damage to food products

Drawbacks

- Its use for products other than fresh fruits and chicken needs to be investigated
- Duration of protection afforded for different food items has not been systematically studied on actual food items
- Cost of production for biodegradable films are still high

Research indicates that mango peel-based packaging films carry significant antioxidant and antimicrobial properties. This biobased innovation, with further research, has the potential to be used as an active packaging solution and reduce plastic packaging waste.

References

1. https://doi.org/10.1111/ijfs.12385
2. https://doi.org/10.1016/j.lwt.2018.07.057
3. http://iopscience.iop.org/article/10.1088/1757-899X/309/1/012068/pdf
4. https://doi.org/10.1016/j.fpsl.2018.01.006

SeaWell: Preserving frozen and fresh seafood

Moisture absorbers are commonly used to control excess water accumulation inside the packages of food with high moisture content such as meat, fish, poultry and fresh produce. Recent years have seen innovations that combine various polymers to control moisture, which inhibits microorganisms and mold to increase the freshness of food. SeaWell Packaging Solutions has introduced a packaging line to extend the shelf life of frozen and fresh seafood.

At a glance

Type	Moisture-absorbent packaging
Year	2018
Key Feature	Automation-friendly, integrated absorbent technology
Current Application	Frozen and fresh seafood
Applicability	Protein-rich products, industrial kitchens (high-speed production environment)
Main Limitation	Patent pending

Technology

SeaWell Seafood packaging trays designed by Aptar Food + Beverage (previously called Maxwell Chase) are designed for significantly enhancing the shelf life of both fresh and frozen seafood. The trays are made of recyclable polypropylene and feature an integrated absorbent technology incorporated into wells at the bottom to absorb excess fluids. With the superabsorbent polymer, the tray acts as an active water scavenging system to prevent the exposure of food to fluids. Consequently, these trays lower any potential damage to seafood products.

The company claims that the technology can extend the shelf life of fresh seafood by 50% or even more. Along with extending the shelf life of frozen and fresh seafood, the trays can also work for other protein products such as meat.

SeaWell: Preserving frozen and fresh seafood

Benefits

- The trays also help in keeping the food fresh, safe, free of odors, and damage
- Automation-friendly, these trays are suitable to be used in places with a high-speed production environment
- The seafood can be packed frozen and thawed in the same package without affecting the product integrity. Moreover, the fluids absorbed in the tray's wells and are invisible to the consumers

Drawbacks

- The technology is currently in the patent-pending stage

Recent Developments & News

On July 9, 2020, Aptar Food + Beverage, part of AptarGroup, Inc. and a leader in a broad range of food protection solutions and proprietary active packaging systems for seafood and fresh-cut fruits and vegetables, launched its ***SEAWELL™ Protective Packaging System*** with a leading national retailer in more than 3,800 store locations.

The company claims that SeaWell seafood trays have the potential to revolutionize the seafood industry. Other protein products such as meat products are being tested to be packaged using this technology. The company is working with different customers at different stages of commercialization.

References

1. https://www.foodsafetystrategies.com/articles/269-seafood-packaging-trays-extend-product-shelf-life
2. https://www.packagingdigest.com/trays/shelf-life-food-safety-increase-seawell-seafood-trays1803
3. http://www.maxwellchase.com/news-january-26-2018/
4. https://www.seafoodsource.com/seafood-expo-north-america-2018/new-seafood-trays-optimized-for-extended-shelf-life-to-launch-at-seafood-expo-north-america
5. https://onlinelibrary.wiley.com/doi/full/10.1111/1541-4337.12343
6. https://www.perishablenews.com/seafood/aptar-food-beverage-announces-market-launch-of-seawell-an-active-packaging-system-designed-to-maintain-seafood-quality-and-freshness/

Graphene oxide for on-demand preservatives

Preservatives such as benzoic and sorbic acid that are often added to the surface of fruits have been found to be toxic for humans. And the parabens in preservatives based on natural extracts can have negative physiological and environmental side effects. Furthermore, different fruits require different amounts of preservatives at different stages of ripening. Thus, researchers at the Institute of Nano Science and Technology are creating a wrapper that takes in stimuli from each fruit to determine the dosage of preservatives it should release.

At a glance

Type	Preservative packaging
Year	2018
Key Feature	Stimulated by fruit to release preservative from wrapper
Current Application	Bananas
Applicability	Fruits
Main Limitation	Not tested on other types of food

Technology

The wrapper itself is made out of graphene oxide (GO), which has a high surface area and is inert to prevent the wrapper from reacting with the preservative. The preservative used is salicylaldehyde (SA), and bananas were used as a sample fruit. The GO-SA composite is dispersed on filter paper to prevent direct contact with the fruit.

As bananas ripen, they release acids which triggers the release of SA from the wrapper and slows down the ripening process. Using the graphene oxide base provides antimicrobial protection on the fruit against two common microbes in plants, *E. coli* and *P. syringae*.

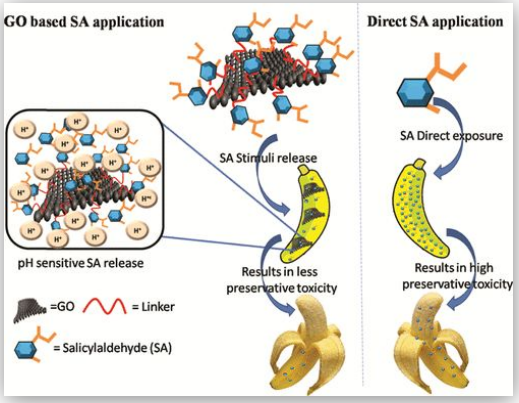


Figure: Graphical abstract from: Ecofriendly Fruit Switches: Graphene Oxide-Based Wrapper for Programmed Fruit Preservative Delivery To Extend Shelf Life

Graphene oxide for on-demand preservatives

Benefits

- The preservative delivery is triggered by the release of acids by ripening fruits, so this technique should be applicable to other fruit products
- Minimal toxicity as neither the GO nor the SA can pass through the filter paper used in the wrapper into foods
- Wrapper is flexible and has tensile strength comparable to normal cellulose-based paper

Drawbacks

- This technique has not been investigated for other types of food products (grains, dairy, meats)
- Composite may be lost to the environment, which could pose environmental risks
- Bacteria can interact with GO, changing its surface characteristics
- Effects of wrapper on the rate of ripening at the very late stages of the ripening process is minimal

This technology meets three important criteria: antimicrobial, controls ripening and is not in direct contact with fruit. However, this GO wrapper may have limitations in the later stages of ripening, when the acid content reduces and the late polymerization forms a lignin. The researchers plan to address this challenge in their next step of research.

References
1. https://pubs.acs.org/doi/10.1021/acsami.8b02048

Apeel's edible coating

Food-tech startup Apeel Sciences has developed an invisible, edible coating to be sprayed on produce for shelf life extension. The company claims the coating slows decay, allowing their avocados to 2x as long as conventional avocados. Apeel introduced its avocados at Costco and Harps food store locations in the US Midwest. The company has raised $40M from high-profile investors such as the Bill and Melinda Gates Foundation and an additional $70M in a funding round led by Viking Global Investors, Andreessen Horowitz, Upfront Ventures, and S2G Ventures.

Technology

Apeel uses plant-based materials such as the leftover peels of fruits and vegetables to develop an invisible natural coating. The coating is tasteless and is safe as per the criteria of the FDA. It starts off as a powder that is mixed with water to create a solution that is applied to produce as a dip or spray. The coating controls both the rate at which water escapes from the surface of fruits and vegetables and the rate at which oxygen enters.

The coating acts as a protective seal slowing down the decay and thus the oxidation process. After the coating dries, it locks in moisture and acts a barrier against natural gases including ethylene and oxygen to ripen the avocados. The cost of avocados treated with the coating is the same as the conventional ones with an extended shelf life.

At a glance

Type	Invisible coating
Year	2016
Key Feature	Edible, plant based
Current Application	Avocados
Applicability	Fruits, vegetables
Main Limitation	Coating cannot be washed off

Figure: A comparison of untreated avocados (left) and avocados treated with Apeel's edible coating (right) after 26 days.

Apeel's edible coating

Benefits

- Natural, clean-label ingredients
- Coating is safe for human consumption
- Tested on more than 20 different fruits and vegetables
- Tasteless, odorless and colorless
- Prolongs shelf life significantly, in some cases doubling i

Drawbacks

- Produce must be clean before applying Apeel coating
- Coating cannot be washed off

Recent Developments & News

On May 26, 2020, Apeel announced $250M in new financing to improve resilience of fresh food supply chain and fight global food waste.

On Sept 22, 2020, Apeel Sciences and Houweling's Group partnered to launch plastic-free cucumbers in Walmart to increase shelf life and reduce plastic and food waste.

On Jan 8, 2021, Apeel CEO announced plans to to expand into markets in Asia, Africa, and Latin America.

Apeel is looking to help preserve fruits and vegetables in areas such as developing countries, where refrigeration is not widely available across the supply chain.

References

1. https://apeelsciences.com
2. https://www.theguardian.com/lifeandstyle/2018/jun/19/edible-coating-allows-avocados-to-stay-ripe-for-twice-as-long
3. https://www.cnbc.com/2018/06/19/apeel-which-makes-coating-to-preserve-produce-signs-costco-deal.html
4. https://www.businessinsider.com/costco-bill-gates-apeel-sciences-avocado-2018-6
5. https://www.designboom.com/technology/costco-apeel-sciences-avocado-preservation-06-20-2018/
6. https://www.prnewswire.com/news-releases/apeel-sciences-announces-250m-in-new-financing-to-improve-resilience-of-fresh-food-supply-chain-and-fight-global-food-waste-301065188.html
7. **https://www.wsj.com/articles/apeel-ceo-james-rogers-wants-to-extend-the-shelf-life-of-your-avocados-and-oranges-11610128693**
8. https://foodtank.com/news/2020/11/plastic-free-cucumbers-reduce-plastic-and-food-waste/

Antioxidant packaging with nanoselenium

Researchers at the University of Zaragoza are exploiting the scientifically established antioxidant properties of selenium nanoparticles to develop a flexible, multilayer active packaging solution. The packaging was tested both in the laboratory and on an industrial scale. This is the first study where an industrial active multilayer containing selenium nanoparticles as an antioxidant agent is investigated.

At a glance

Type	Multilayer packaging
Year	2018
Key Feature	Antioxidant, flexible
Current Application	Hazelnuts, walnuts, potato chips, cooked ham, chicken, ready-to-eat vegetables
Applicability	All types of packaged goods
Main Limitation	Does not improve barrier properties, hexanol values unreliable in the tests

Technology

Antioxidant packaging acts by absorbing compounds such as oxygen or free radicals that lead to food deterioration. Researchers have built and optimized a flexible multilayer material containing the antioxidant nanoselenium (nanoSe). The nanoSe was placed in the middle of the multilayer to not affect the performance of the plastic film.

The nanoSe packaging was tested with food susceptible to rancidity in the lab as well as on an industrial scale.

In the lab, researchers studied the fatty acid content, malondialdehyde (MDA) levels and sensory profile of hazelnuts and walnuts placed in the nanoSe packaging. For all tests, nuts placed in the nanoSe packaging showed higher fatty acid content, lower levels of MDA, and a better sensory profile after 42 days when compared to the control group. Potato chips were also studied and showed a 22% decrease in MDA.

On an industrial scale, cooked ham, chicken, and a ready-to-eat vegetable mixture seasoned with butter were tested. After 21 days, the most significant decrease in MDA was seen with ham (50% decrease).

Antioxidant packaging with nanoselenium

Benefits

- Evaluated and received a positive opinion from EFSA (European Food Safety Authority)
- No migration of selenium nanoparticles to food
- Performance as a strong free radical scavenger was demonstrated successfully with the lab and industrial tests
- Multilayer with Se nanoparticles performs well in lab as well as on an industrial scale

Drawbacks

- Does not enhance the barrier properties of the multilayer for organic vapors, such as aldehydes
- Hexanal, the main product of linoleic oxidation by nuts was not reliable

By acting as a scavenger of free radicals, the presence of nanoSe in this packaging delays the oxidation of food materials. With the new antioxidant material, considerable improvements in the food products have been confirmed. The incorporation of selenium nanoparticles in packaging materials seems to be a promising new method for improving the shelf life of packaged foods.

References
1. https://www.mdpi.com/2079-4991/8/10/837/pdf

Notable techs from 2021

RipeLocker for perishable produce preservation

RipeLocker containers use a patented system to regulate atmospheric pressure, humidity as well as O_2 and CO_2 composition, suppressing the growth of microbes that lead to decay.

Users can regulate internal pressure and oxygen/CO2 levels to optimize the storage longevity. The containers also respond to changes in storage / shipping environments and are designed to be deployed and used in existing supply chains.

In a recently completed trial with blueberries, these reusable containers kept blueberries pristine for over 2 months and pomegranate fresh for 5 months, as reported by the company.

SAVRpak for cooked food storage

SAVRpak, winner of P&G Ventures CES 2021 Innovation Challenge, has developed a frozen peel-and-stick patch that forces moisture from the air of a container before it converts into condensation. This moisture pack technology can extend shelf life up to 50% according to the company.

The main application has been restaurants and food delivery, keeping food fresher during transit or storage.

Next-Generation Additives

Next-Generation Additives

An interesting push in this area is not only the use of plant- and food-based additives, but also using components previously thought of as waste. In recovering food waste for use as additives, not only can food shelf life be extended, but the industry also sees a reduction in waste.

Research focus has primarily focused on two areas: essential oils & foods. Oxikan is utilizing antioxidants from rosemary, whereas a UBC research group has combined essential oils with fruit acids.

University researchers have shown that banana-derived cellulose nanofibrils slowed the melting of ice cream whereas others are using pomace as a food preservative. Kemin is seeking plant-based extracts to replace EDTA and found success with rosemary, spearmint, and green tea extracts.

5 Next-Generation Additives for Extending Shelf Life

The Major Features of Each Technology

Technology	Company / Organization	Phase	Food Use Approval[1]	Type	Year
Banana-Derived Cellulose Nanofibrils	Universidad Pontificia Bolivariana	Research	✓	Stabilizer	**2018**
Plant-Based Alternative for EDTA	KEMIN	Prototype	✓	Chelating agent	**2018**
Fruit Juice / Essential Oil Blend	UBC	Research	✓	Natural preservative	**2018**
Grape Waste Additive	University of Nebraska Lincoln	Research	✓	Antioxidant	**2018**
OxiKan CL	KANCOR MANE	Product	✓	Antioxidant	**2016**

[1] *Approved for food use based on the plant-based or food-based nature of solution*

Banana-derived cellulose nanofibrils

For several years, scientists struggled to overcome the challenges to increase the shelf life of ice cream. Most importantly, it can melt easily at room temperatures. Research shows that adding agricultural waste to ice cream may have some benefit. Scientists at Pontifical Bolivarian University have found that cellulose nanofibrils (CNFs) derived from banana waste could slow melting and increase the shelf life of ice cream.

At a glance

Type	Banana waste–based additives
Year	2018
Key Feature	Banana-derived cellulose nanofibrils (CNF), low-fat ice cream
Current Application	Ice cream
Applicability	Long-lasting, low-calorie ice creams
Main Limitation	Tests performed in closed chambers, effects of wind not determined, labor intensive

Technology

Researches isolated cellulose from banana stalks and used a specific machine to extract tiny bits of cellulose (nanofibrils) from ground-up banana stalks. These nanofibrils are tiny — 1000 times smaller than the width of a human hair. The team found that adding CNFs at a concentration of 0-0.3g per 100g of ice cream at 20°C caused a delay in the melting rate.

Scientists evaluated the effects of CNFs on ice cream, and the results showed that the addition of CNFs to ice cream made it less sensitive to temperature changes and slowed melting. The CNF-enriched low-fat ice cream showed a higher viscosity, improved creaminess, and texture than its regular counterpart, which could be due to CNFs stabilizing of the structure of fats in the ice cream.

Figure: CNFs extracted from the stalks (red) of banana trees

Banana-derived cellulose nanofibrils

Benefits

- Melt-resistant ice creams with lower calorie counts and improved texture
- Even in hot weather, CNF-enriched ice creams can be enjoyed for longer periods of time

Drawbacks

- The researchers performed the experiments in a closed air chamber with no air movement. Air currents or wind can affect the melting behavior differently
- Currently, the process of extracting large amounts of cellulose from banana wastes is labor intensive

This innovation could mean huge gains for the ice cream industry. The researchers plan to finish some more experiments before the technology goes to market. Currently, the plan is to investigate how different types of fat, including coconut oil and milk fat, could affect the properties of CNFs in other frozen treats. The team is also working to make the process of cellulose extraction from banana waste more efficient. Many ice cream makers add hydrocolloids for the shape retention and prevention from dripping. The scientists are interested in testing if CNFs are superior to standard hydrocolloids.

References

1. https://www.sciencedaily.com/releases/2018/03/180321090941.htm
2. https://newatlas.com/banana-waste-ice-cream/53901/
3. https://www.deccanchronicle.com/lifestyle/food-and-recipes/220318/this-plant-extract-will-keep-ice-cream-from-melting.html
4. https://www.sciencenewsforstudents.org/article/banana-plant-extract-can-slow-ice-cream-melt
5. https://www.studyfinds.org/melt-resistant-ice-cream-banana-extract/

Plant-based extracts as alternatives to EDTA

Kemin Industries has introduced NaturFORT RSGT as a plant-based shelf life extension solution for salad dressings and sauces. A blend of rosemary, spearmint, and green tea plant extracts, it is a replacement for the chelating agent EDTA traditionally used as a food preservative, additive, color enhancer, and stabilizer. Chelating agents react with metal ions to form water-soluble complexes that prolong the shelf life of food items. NaturFORT retains its chelating abilities much like EDTA and is not affected by changes in pH, which helps to extend shelf life.

At a glance

Type	Natural plant-based additive
Year	2018
Key Feature	Alternative to EDTA
Current Application	Mayonnaise, salad dressings, and sauces
Applicability	Replace EDTA as chelating agent in other food matrices
Main Limitation	Higher doses are required to match EDTA performance, ranch dressing not receptive to the blend

Technology

The company screened many plant extracts to determine the effects on delaying lipid oxidation in emulsions, with mayonnaise as a model. Mayonnaise was treated with known chelating agents and candidate plant-based ingredients. The peroxide value that correlates with the oxidative deterioration was monitored over a 4-week storage period. Among the extracts tested, the spearmint solution was most effective.

A solution with rosemary, spearmint, and green tea extracts showed optimal performance and effectiveness in studies. Rosemary targets the oil phase when added to an emulsion, and spearmint and green tea target the aqueous phase. The blend slows down lipid oxidation, reduces the byproducts of oxidation and therefore enhances shelf life. The solution is used to extend the shelf life of sauces and dressings.

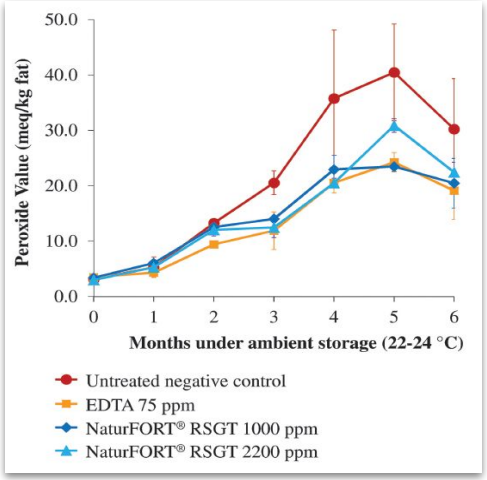


Figure: A comparison of peroxide values in mayonnaise treated with EDTA and NaturFORT

Plant-based extracts as alternatives to EDTA

Benefits

- The company provides manufacturers a consumer-friendly alternative for the shelf life extension of foods
- The studies show a shelf life evaluation of up to 6 months with the solution

Drawbacks

- Higher doses of the solution are required to match the performance of EDTA
- The blend needs further optimization and is dependent on the type of food emulsions.
- Dose-response results were not found in the ranch dressing study
- Oxidative stability tests of various other food matrices need to be performed to determine the efficacy of the solution

Recent Developments & News

On Jan 30, 2019, Kemin announced the launch of another clean label food safety ingredient made from buffered vinegar and plant extracts in Europe to extend the shelf-life and stabilize the color of processed meats. The product is called NaturCEASE.

On Dec 31, 2020, Kemin announced the launch of Fortium R rosemary extract antioxidant that helps maintain taste and texture in refrigerated, plant-based meat alternatives.

Kemin's innovation is a promising start for manufacturers looking for an alternative to EDTA in their list of ingredients. Currently, the company is in the process of optimizing the blend to enhance the performance of shelf life extension past six months.

References

1. https://www.foodnavigator-usa.com/Article/2018/05/16/Kemin-introduces-plant-based-alternative-to-EDTA-for-shelf-life-extension
2. https://www.preparedfoods.com/articles/121228-kemin-extend-shelf-life
3. http://www.nutritionaloutlook.com/food-beverage/new-botanical-extract-blend-extends-shelf-life-dressings-and-sauces-natural-alternative-chemical
4. http://www.informmagazine-digital.org/informmagazine/july_august_2018/MobilePagedArticle.action?articleId=1406135#articleId1406135
5. https://www.foodnavigator.com/Article/2019/01/30/Kemin-combats-microbial-spoilage-in-processed-meat-with-clean-label-ingredient
6. https://www.foodbusinessnews.net/articles/17563-kemin-offers-oxidation-control-for-plant-based-meats

Natural preservatives for fruit juice

Fruit juices contain vitamins, minerals, and fiber that help sustain a healthy lifestyle. However, some of the nutrients in fruits (carotenoids, phenolic compounds) are heat sensitive, so thermal treatments of fruit juices may lower the nutritional value and alter the taste. Essential oils derived from plants have antimicrobial properties, but their strong flavors can also affect the taste of the end product. To solve these issues, researchers at the University of British Columbia are investigating the use of natural acids from other fruits combined with essential oils as a natural preservative.

At a glance

Type	Natural preservative
Year	2018
Key Feature	Natural, nonthermal, antimicrobial
Current Application	Watermelon juice
Applicability	Fruit juices
Main Limitation	Altered appearance

Technology

Essential oils from cloves and cinnamon were extracted and added to watermelon juice, Researchers used this as a test case. A blend of apple and lemon juice was added to this mix to mask the taste of the essential oils with the tartness of the apple/lemon blend.

A 60:40 ratio of watermelon and apple/lemon juices with 0.02% essential oils was found to have the most palatable taste by a panel of 50 judges while extending the shelf life of the juice to almost 14 days, due to the combined effects of acidity from the apple/lemon blend and antimicrobial activity of the essential oils.

Natural preservatives for fruit juice

Benefits

- Ingredients are all-natural, derived from fruits or other plants
- No thermal process is required so there is no loss of nutrients from the final product
- Using apple/lemon juice blend masks the unpleasant taste of essential oils

Drawbacks

- Appearance of final product is altered due to the additives
- Adding a higher percentage of essential oils makes the final product unpalatable to consumers
- Approach still needs to be investigated for products other than watermelon juice

The combination of natural acids from low-pH fruits and essential oil constituents could be a potentially effective way to extend the shelf life of fruit juices, nonthermally and organically. Further research needs to be done for other types of fruit juice.

References
1. https://doi.org/10.1111/1750-3841.14277

Grape waste from wine-making

The wine industry produces about 14 million tons of pomace, a pulpy grape waste that can cause surface and groundwater pollution, due to the pesticides and fertilizers applied to the grapes. Pomace in landfills also turns the soil acidic and poses a risk to human health by attracting flies and pests. Researchers from the University of Nebraska-Lincoln have extracted the nutrients from pomace and converted it into beneficial ingredients that will increase the nutritional value of food products and enhance the shelf life of fatty foods.

At a glance

Type	Agricultural waste
Year	2018
Key Feature	Natural antioxidants, antimicrobial agents, prevents lipid oxidation
Current Application	Mayonnaise and ranch dressing
Applicability	Fatty foods
Main Limitation	Optimizing technology to extract, separate, and identify the nutrients from grape pomace

Technology

Antioxidants in pomace such as proanthocyanidins, anthocyanins, and ellagic acid can bind to free radicals and protect the cells from damage. In a trial, researchers separated the antioxidant compounds in grape pomace from pesticides and other compounds. Then they added the formulation to high-fat foods including mayonnaise and ranch dressing.

The results showed that the antioxidant formulation prevented the lipid oxidation of these products even at warm temperatures. Encouraged by these results, the group intends to substitute artificial antioxidants with natural antioxidants in grapes for the shelf life extension of high-lipid human and even animal food products.

Currently, the researchers are optimizing technologies to remove pesticides on the surface of the grapes, extract, separate and identify nutrients from grape pomace.

Grape waste from wine-making

Benefits

- Polyphenols in grape pomace can act as natural antioxidants and potential antimicrobial agents
- They could protect food from foodborne pathogens such as *E. coli* and salmonella
- Recycling grape pomace can help wine companies to reduce environmental damage and make economic profits as well

Drawbacks

- The team requires optimal technologies to extract, separate and identify the nutrients from grape pomace before widespread commercial applications

This technology would not only increase the economic value of the grape and wine industry but will also reduce environmental pollution. The antioxidants in pomace could also potentially replace EDTA in many food products. The team is currently working to enhance the efficiency of the solution and ability to inhibit lipid oxidation.

References

1. https://xtalks.com/grape-waste-from-wine-making-process-found-to-be-a-natural-preservative-1250/
2. https://www.sciencedaily.com/releases/2018/03/180319090734.htm
3. https://food.news/2018-04-22-repurposing-wine-leftovers-waste-from-grapes-found-to-have-many-uses.html

Kancor: OxiKan CL

Lipid oxidation is one of the main reasons for the deterioration of food products, lowering the nutritional value and appeal due to unusual odors and flavors. Antioxidants prolong the shelf life of food items by delaying the process of lipid oxidation, thus preventing degradation and lipid rancidity. Kancor has identified three kinds of antioxidant molecules in rosemary that can prevent the oxidation of other molecules by being oxidized themselves.

At a glance

Type	Antioxidant
Year	2016
Key Feature	Natural, clean-label, delays lipid oxidation
Current Application	Potato chips, foods processed at high temperatures
Applicability	Beverages, specialty fats, Omega-3 fortified products
Main Limitation	Not suitable for infant food products

Technology

Kancor has developed a natural antioxidant solution derived from rosemary called OxiKan CL. OxiKan CL is a fully colorless, odorless and flavorless liquid extract that does not alter the organoleptic profile of the food matrix. It extends the shelf life of the food products by fighting lipid rancidity without imparting any aroma or color.

The company claims that OxiKan CL is an ideal natural antioxidant solution for sensitive food products such as popcorn, beverages, spreads, and dressings.

While OxiKan CL is oil soluble, OxiKan CLS is a water-soluble variant. Both antioxidant solutions possess excellent oil and heat stability. OxiKan CL is currently being used to extend the shelf life of potato chips and other foods processed in high-temperature conditions.

Figure: Color-impact comparison of OxiKan CLS, the water-soluble version of OxiKan CL, to rosemary extract in citrus beverages

Kancor: OxiKan CL

Benefits

- The absence of unwanted molecules such as chlorophyll, carotenoids, and xanthophylls makes OxiKan CL superior to other natural antioxidants
- It is most suitable for applications that are sensitive to the aroma, flavor, Omega 3 fortified products, and beverages
- Free from irradiation, non-GMO, halal and kosher certified

Drawbacks

- Although OxiKan Cl is free of allergens, it is not allowed for use in infant food at the moment

Recent Developments & News

In March of 2019, Kancor released a technical paper covering an oxidative stability study on refined sunflower oil in deep-frying conditions using another rosemary-based antioxidant called OxiKan R.

Kancor is in the process of improving variants of OxiKan CL. It recently won the IFT 2018 Food Expo Innovation Award for their comparative study on prolonging the shelf life of popcorn. Extensive application studies are underway to study the efficacy of OxiKan on various food products including snacks, meat patties, chips, fats, and oil-beverages. If successful, some synthetic antioxidants can potentially be replaced with this natural, clean-label ingredient.

References

1. https://www.dairyreporter.com/Product-innovations/The-secret-ingredient-that-extends-the-shelf-life-of-beverages-naturally
2. https://www.foodnavigator.com/Suppliers/Kancor-Ingredients-Limited
3. https://www.foodingredientsfirst.com/news/antioxidant-breakthrough-kancor-wins-ift-innovation-award-for-oxikan-cl.html
4. https://www.kancor.com/category/products/specialty-ingredients/natural-anti-oxidants/oxikancl/
5. https://www.potatobusiness.com/processing2/2004-natural-antioxidant-to-extend-potato-chips-shelf-life
6. https://www.globalmeatnews.com/Product-Innovations/OxiKan-CL-A-breakthrough-in-natural-anti-oxidants
7. https://www.ingredientsnetwork.com/Kancor%20Mane%20OxiKan%20R%20Plus-file079814.pdf
8. https://www.foodnavigator.com/Product-innovations/Stable-antioxidants-for-deep-frying-applications

Notable techs from 2020

Peanut skins as an antioxidant

Researchers have reported a new way to combine milk chocolate with waste peanut skins and other wastes (such as coffee waste) to boost its antioxidant properties. Thousands of tons of peanut skins are discarded each year, but since they contain 15% phenolic compounds by weight, they're a potential goldmine of antioxidant bioactivity. Researchers have exploited this feature and plan to further explore the use of peanut skins, coffee grounds and other waste products into additional foods. In particular, the research team is hoping to test whether the antioxidants in peanut skins extend the shelf life of nut butters, which can go rancid quickly because of their high fat content.

Mushroom-based preservative for plant-based dairy

CHINOVA BIOWORKS

After launching its Chiber™ natural preservative made from chitosan, a biopolymer extracted from mushrooms which prevents spoilage in a variety of products including plant-based dairy alternatives, Chinova Bioworks has solved another issue facing plant-based dairy producers: the preservation of products' probiotic counts throughout an extended shelf life.

A pilot test was conducted with a probiotic-containing cashew yogurt. Results showed a 60% reduction of mold growth in the product at the end of shelf-life. Additionally, probiotic bacteria counts were the same level as the control with no Chiber™, according to the company.

Food Treatment Methods

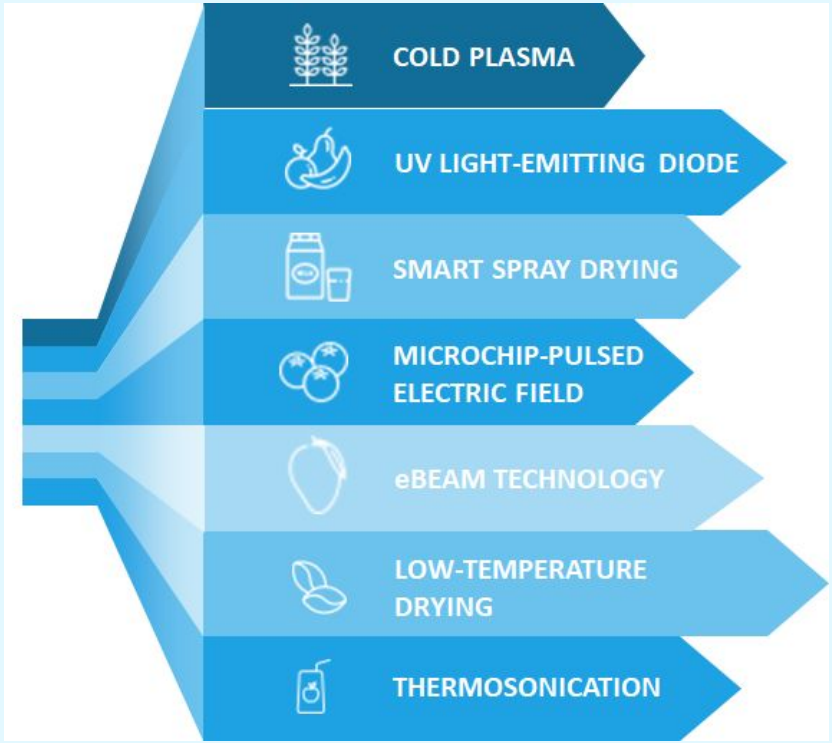
Food Treatment Methods

Another distinct avenue of focus is by treating the food (primarily on its surface) to help prevent decay mechanisms from occurring.

Most of the treatments profiled here strive to remove or neutralize microbes on/within food prior to being packaged. With far fewer active microbes packaged with the food prior to being sold, researchers have seen a significant reduction in spoilage mechanisms and an overall improvement in shelf life stability. With this, factors to consider include scalability, commercialization, safety, functionality, etc.

Some of the techniques outlined will be fairly easy to commercialize - like UV light treatments, pulsed electric fields, etc; whereas other techniques like thermosonication are typically done in smaller batches and would require fairly high development costs to scale up.

7 Food Treatment Methods for Extending Shelf Life



The Major Features of Each Technology

Technology	Company / Organization	Phase	Thermal	Effect on Functionality	Year
Cold Plasma	Murdoch University, Iowa State University	Research	✗	✓	**2017/2018**
UV Light-Emitting Diodes	Agriculture and Agri-Food Canada	Prototype	✗	✗	**2018**
Smart Spray Drying	Monash University	Prototype	✓	✗	**2018**
Microchip-Pulsed Electric Field		Research	✗	✓	**2018**
eBeam Technology		Prototype	✗	✗	**2017**
Low-Temperature Drying	University of Nottingham	Research	✓	✗	**2018**
Thermosonication		Research	✓	?	**2017**

Cold plasma

Cold plasma (CP) is a mixture of atoms, ions, and excited molecules at temperatures in the range of 25-450°C. CP is generated by applying electric current to a mixture of gases such as argon, nitrogen, or air. Both the medical and dentistry industries use CP as a disinfectant because it eliminates fungi and bacterial growth from surfaces. Researchers from Murdoch University and Iowa State University reviewed the potential of the CP technology for postharvest disease control (especially fungal growth) and its effect on food quality, respectively.

At a glance

Type	Dry, nonthermal process
Year	2017/2018
Key Feature	Elimination of fungal and bacterial growth on surfaces
Current Application	Medical and dental industry
Applicability	Produce, grains, poultry
Main Limitation	Can physically damage delicate foods

Technology

In the food industry, CP is generated mainly from air with other noble gases at room temperature and pressure, which makes it chemically safe for direct contact with food. Three different methods are available for treating food with CP:

- **Direct:** The food sample acts as the second electrode needed to generate CP, bringing the sample into direct contact with the plasma
- **Indirect:** The plasma is generated in a closed circuit and then discharged as a jet onto the food sample
- **Hybrid:** The food sample acts as the second electrode, but a ground electrode is added to lower direct exposure of electric current to the food

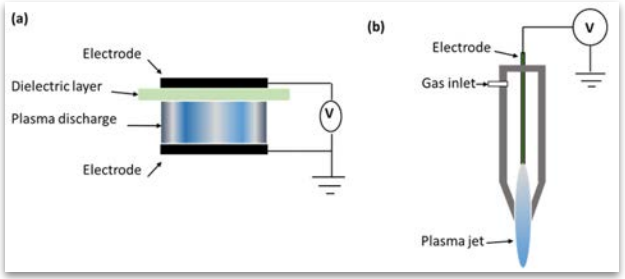


Figure: Schematic diagram of (a) dielectric barrier discharge; (b) plasma jet system.

Cold plasma

Benefits

- It has been shown to be effective at stopping fungus germination at low temperature
- It leaves no residues on the food itself
- It produces no waste
- Feed costs are low since the only feed needed is air

Drawbacks

- Due to its high flow rate, plasma may physically damage delicate foods
- Possible loss of color at prolonged treatment times
- Especially in liquid food products, pH change has been observed
- The process by which CP stops germination is still not understood

Since this technology is still in the research stage, most experiments conducted have been in controlled laboratory environments and not in actual food packaging facilities. More test cases in facilities under various air conditions need to be conducted to gauge the effectiveness of this treatment in different regions of the world. Further research is also needed to determine the effect of CP on the physicochemical properties (such as pH, acidity, proteins, enzymes, vitamins, and lipids) and sensory properties at the molecular level.

References

1. https://doi.org/10.1111/ppa.12825
2. https://dx.doi.org/10.3390%2Ffoods7010004
3. https://www.foodsafetynews.com/2016/12/cold-plasma-proving-to-be-hottest-new-food-safety-treatment/

Agriculture and Agri-Food Canada

UV light-emitting diodes (LEDs)

UV-C radiation is a nonionizing radiation and serves as a promising sanitizing technology for food, especially fresh-cut products. UV-C offers several advantages: no residue, no legal restrictions, easy to use, and no requirement for extensive safety equipment to be implemented. Agriculture and Agri-Food Canada (AAFC) is researching the efficacy of 277-nm UV LEDs for the inactivation of certain foodborne pathogens and mold spores on the surfaces of romaine lettuce and apples.

At a glance

Type	Superficial, nonionizing radiation
Year	2018
Key Feature	Damage microbial DNA, inhibiting proliferation
Current Application	Air & water disinfection
Applicability	Produce
Main Limitation	Relatively short lifespan of LED lamps compared to mercury lamps

Technology

UV-C light has a wavelength range of 200-280 nm and has been found to be effective at inactivating common food pathogens because this wavelength range aligns with the absorbance of DNA (at 260 nm). UV LEDs can be incorporated in various types of machines, from conveyor belts to chiller units. Since LEDs are more effective in colder temperatures, they lend themselves particularly well to use in chiller units and refrigerators. Many food items, including dairy and fruits, are already being processed with UV light.

In AAFC investigations of the efficacy of UV-C LEDs for the inactivation of foodborne pathogens and mold spores on the surfaces of romaine lettuce and apples, UV-C LEDs in the range of 275–280 nm were found to have the optimal trade-off between cost, lifetime, germicidal efficacy, and power output.

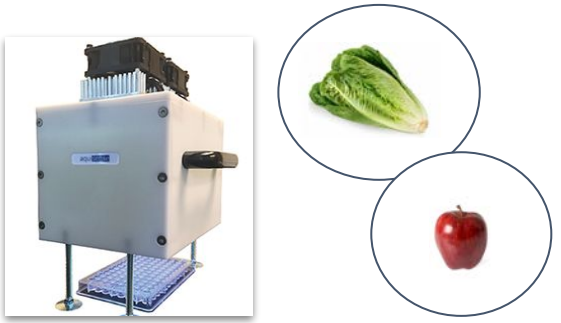


Figure: An example of a UV disinfection box that allows treating whole fresh produce samples

Agriculture and Agri-Food Canada

UV light-emitting diodes (LEDs)

Benefits

- UV-C LED doesn't require heat or chemicals to disinfect food
- LED lamps do not contain the toxic chemical mercury, which makes it safer than traditional mercury lamps
- LED lamps can be used in cold environments
- LED lamps can emit a variety of wavelengths, which allows the tuning of the wavelength these LED lamps emit to match the wavelength of specific microbes for maximum effectiveness
- LED lamps are smaller in size, which allows for more variety in disinfectant equipment designs

Drawbacks

- The current lifetime of LED lamps (10,000 hours) is still much shorter than the lifetime of mercury lamps (12-18,000 hours)
- LED lamps are sensitive to high temperature and humidity
- LED lamps can overheat, further reducing their lifetimes

UV LEDs present a potential solution for the control of food pathogens and extension of shelf life throughout the supply chain. The main issues with UV LEDs are their shorter lifetime compared to mercury lamps and the drop in power output when wavelengths less than 265 nm are used, which lowers the efficiency in eliminating pathogens. A more consistent power output over the full range of wavelengths and longer lifetimes would make this more suited for implementation.

References

1. https://www.foodsafetymagazine.com/magazine-archive1/augustseptember-2018/uv-light-emitting-diodes-the-upcoming-solution-for-enhanced-food-safety/
2. https://www.ledsmagazine.com/articles/2013/05/seti-and-the-usda-document-uv-leds-extending-shelf-life-of-fresh-produce.html
3. https://doi.org/10.1016/j.ifset.2018.03.019
4. https://doi.org/10.1016/j.fm.2016.10.002
5. https://www.foodprocessing.com.au/content/processing/article/applications-for-uv-light-in-the-food-industry-1291409884
6. https://www.ndt.net/article/wcndt2012/papers/357_Breit.pdf
7. http://dx.doi.org/10.5772/intechopen.69476
8. https://en.wikipedia.org/wiki/Ultraviolet_germicidal_irradiation

Smart spray drying

Many dairy products, including baby formula and milk, are sold in powder form, which allows for a longer shelf life. Spray drying works by rapidly heating a liquid or slurry with hot gas to turn it into powder. Using slurries at higher solid concentration improves the efficiency of the process and decreases the energy cost, but a thicker slurry makes the flow of the feed more difficult and can cause pipeline blockages. Researchers are investigating the use of hydrodynamic cavitation (HC) as a pre-treatment to spray drying to resolve this issue.

At a glance

Type	Hydrodynamic cavitation pre-treatment for spray drying
Year	2018
Key Feature	Improved drying efficiency
Current Application	Milk
Applicability	Any powdered food product
Main Limitation	Pilot plant not set up yet

Technology

HC is a physical method that involves passing the liquid through a bottleneck to build up pressure, which is then released as kinetic energy in the liquid, creating both a mixing and a heating effect in the liquid. This technique can be used with any powdered food products that utilized spray drying.

Figure: A pilot scale spray dryer in the Monash University food grade lab. Credit: Monash

Smart spray drying

Benefits

- This technique can be used wherever spray drying is already used in the food industry (powdered dairy products, dry seasonings, and instant meals)
- It has been shown that the use of HC is effective at reducing the viscosity of the feed slurry such that feed flow is not impeded
- The use of HC maintains or even improves the functionality of the final powder product, such as its solubility in water

Drawbacks

- This method has not been tested in pilot plants, so cost information for the treatment is not yet available
- Temperature and pressure during the HC process needs to be controlled to prevent runaway reactions; equipment specially made to handle the high temperatures and pressures possible may be needed

Using hydrodynamic cavitation as a pre-treatment in spray drying can potentially improve the drying process and extend the shelf life of powdered dairy products. This is especially important for infant formulas, which are often exported overseas and may not reach the consumer for months after production. Monash University is working with a number of national and international industry partners on this project. Partners include CSIRO, Tamu Innovations, Bega Cheese, and Burra Foods, among others.

References

1. https://phys.org/news/2018-07-technology-shelf-life-dairy-exports.html
2. https://doi.org/10.1016/j.jfoodeng.2017.10.005
3. https://www.fstjournal.org/features/spray-drying-technology-assists-production-food-products-and-ingredients-advanced

Microchip-pulsed electric field

Pulsed electric field (PEF) is a popular nonthermal food preservation technology that works by delivering short (in the order of microseconds) high-voltage electric pulses to beverages flowing between the two electrodes of the treatment chamber. A strong electric field is required to destroy cell walls of microbes, causing cell death. Microchips allow the two electrodes to be very close together so even low voltages are able to produce high electric field strength, which makes it less expensive to run than traditional PEF instruments.

At a glance

Type	Nonthermal, electric
Year	2018
Key Feature	Nonthermal and nonchemical antimicrobial
Current Application	Blueberry juice
Applicability	Fruit juice
Main Limitation	Very slow flow rate

Technology

Both positive and negative electrodes are placed on the microchip, and the sample channel is placed above the electrodes. Blueberry juice is used as a sample and is passed through the channel while exposed to electric pulses from the electrodes. The odor and taste of treated blueberry juice (using microchip-PEF) were compared to that of fresh untreated blueberry juice using e-Nose and e-Tongue equipment and no significant difference was observed. It was found that the shelf life of the juice reached 30 days with this treatment, with no significant losses in vitamin C or acid content.

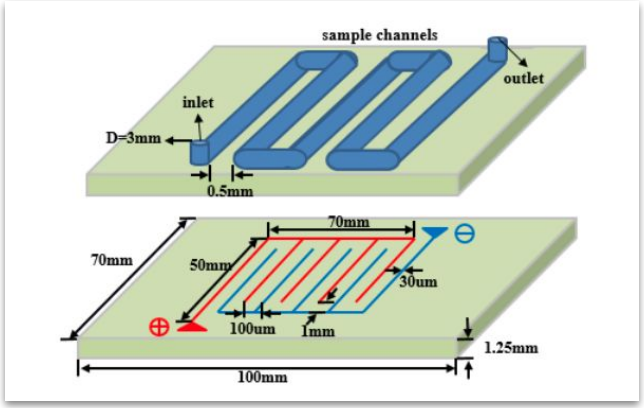


Figure: Schematic of a microchip with the detailed topology parameters. The multi-electrode array (red and blue lines) was etched on a glass basement membrane, and sample channels were etched on the PDMS and set on top of the electrode.

Microchip-pulsed electric field

Benefits

- Visual, odor, and taste characteristics of final product did not significantly change
- No significant losses of nutritional content of final product because treatment is nonthermal
- Lower voltage is needed compared to traditional pulsed electric field technologies

Drawbacks

- Further research is needed to show that a viable high flow microfluidic system suitable for industrial applications is possible
- Effect on other fruit juices, or other beverages in general, has not been investigated
- The efficacy on high viscosity fluids remains a highly likely limitation

The researchers believe that microchip-pulsed electric field could be a better alternative than high-temperature short time (HTST) treatments for the sterilization of fruit juices. Further research should focus on scaling up processes and optimizing the technique to maintain the characteristics of treated beverages.

References
1. https://doi.org/10.1016/j.foodchem.2018.08.092
2. https://doi.org/10.1371/journal.pone.0198467

eBeam technology

Methyl bromide is an effective antimicrobial agent for produce but can be dangerous to the ozone layer and human health. Although the US Department of Agriculture's Animal and Plant Inspection Service (APHIS) uses vapor heat, hot water dips, and cold treatments as alternatives, these treatments are less effective and affect quality. They are especially problematic for mangoes, which, if too ripe, are unfit for hot water treatment. APHIS has allowed eBeams at 0.150-1 kGy to irradiate imported fruits and vegetables to ensure disinfestation.

At a glance

Type	Ionizing radiation technology
Year	2017
Key Feature	Chemical free, nonthermal, foodborne microbial DNA inactivation
Current Application	Mangoes
Applicability	Milk, raw oysters, ground beef, spices, spinach, lettuce, and guavas
Main Limitation	Consumer resistance, slow commercial applications, labor intensive

Technology

eBeam technology is a type of ionizing radiation. An accelerator generates electrons with very high velocity and energy. These energetic electrons can penetrate food particles and cause numerous double-stranded breaks in the DNA, rendering microbial pathogens ineffective. The electrons can further split water molecules and generate short-lived free radicals, which add to the inactivation of the microorganisms.

A representative list of the eBeam doses in kGy has been generated for different foodborne pathogens in different food matrices by the researchers for the eBeam Center at Texas A&M University. In a study, eBeam-pasteurized milk met all the nutritional guidelines of the US Department of Agriculture. Further, no off odors were generated.

A major retailer has partnered with the eBeam Center to meet federal sanitation requirements without damaging the fruit. The goal of the collaboration is to test the use of this cost-effective, eco-friendly technology for commercial use. Moreover, the FDA has approved eBeam for the shelf life extension of foods at high risk for pathogens, such as meats, oysters, spinach, and lettuce.

eBeam technology

Benefits

- eBeam technology eliminates the usage of methyl bromide for the sterilization of food products
- The commercial dose of eBeam applied to the food product is dependent on the target pathogens and is tunable, with no effect on the quality of the food product
- Mangoes treated with eBeam technology remain ripe for longer
- The technology is a cost-effective solution

Drawbacks

- Commercial applications of the technology have been slow
- Some consumers are resistant to the idea of using irradiated food products
- Currently, the process is labor-intensive, and therefore, the next step would be to test automation in the handling of the food products
- Possible health concerns could emerge due to the use of dosages at off-limits
- A thorough risk-based assessment of the dosage needed to sterilize the food products is required

Researchers at the eBeam Center are currently conducting a quantitative microbial risk assessment for the technology. The center is also working to expand the technology by partnering with private companies and public agencies. Private companies are showing an increased interest in building similar eBeam centers in the United States and Mexico. The scope of this technology is immense, as high volumes of food products can be treated with the fine-tuning of the dosage, with no chemical residues.

References

1. https://today.agrilife.org/2018/07/22/ebeam-technology-at-texas-am-tested-in-commercial-use-study/
2. https://www.foodsafetymagazine.com/magazine-archive1/aprilmay-2018/electron-beam-technology-a-platform-for-safe-fresh-and-chemical-free-food/
3. https://www.texasstandard.org/stories/how-an-electron-beam-could-protect-your-mangoes-from-foreign-insects/

Low-temperature drying

Retention of the nutrients from field to fork has remained a challenge for the food industry. Researchers from the University of Nottingham, Malaysia, have developed low-temperature drying to improve the shelf life and the quality of food. Low-temperature drying is efficient at retaining flavor, color, bioactive ingredients, vitamin C, and other nutrients in processed foods. While the conventional drying methods delay spoilage, this method results in a higher-quality product with higher nutrient content.

At a glance

Type	Low-temperature drying
Year	2018
Key Feature	Dehydration at low temperature, retention of color, taste, bioactive ingredients, and nutrients
Current Application	Cocoa beans, fruits, herbs, and edible bird nests
Applicability	Food products in humid environments, minimize harvest loss
Main Limitation	Slow commercialization

Technology

Researchers from the University of Nottingham, Malaysia, discovered that drying lemon myrtle at a lower temperature of 20°C led to significantly improved retention of the bioactive ingredient citral and color than using conventional drying methods at a temperature of 60°C. Since the discovery, low-temperature drying has been used to retain bioactive ingredients and nutrients in cocoa beans, fruits, herbs, and edible bird nests, a delicacy in East Asia.

The technique uses the combination of a heat pump system and a heat transfer module to generate a low-temperature, low-moisture environment for dehydrating food products. The process is performed as a closed-system operation to minimize the chances of contamination. The lemon myrtle leaf powder is spread over a large surface to make the process more efficient.

After drying, air is recycled within the system and a condenser to extract the moisture from the air. An environment of 20°C and 20% humidity is optimal for removing the moisture from foods and herbs, which contain bioactive ingredients and are sensitive to high temperature.

Low-temperature drying

Benefits

- Low-temperature drying eliminates the risk of undesirable chemical reactions that generally take place in other processing conditions such as high temperature drying
- It improves the retention of bioactive compounds, nutritional content, and color
- Compared to thermal drying, drying at low temperature is energy efficient and cost effective

Drawbacks

- Commercialization has been slow for this technique due to the capital cost of using a closed system/controlled environment
- The process is much slower than high-temperature drying

The research has generated widespread interest in industries, and the group is currently working to further improve the technology for collaboration and commercialization in the future. Low-temperature drying is a cost-effective and efficient solution for many companies looking to improve production processes, productive quality especially with products highly sensitive to high temperatures.

References
1. https://www.nottingham.ac.uk/news/pressreleases/2018/may/new-techniques-to-improve-the-shelf-life-of-our-food-could-help-minimize-harvest-loss.aspx
2. https://doi.org/10.1080/07373937.2016.1219741

Thermosonication of apple juice

Ultrasound inactivates microorganisms in two ways: mechanically, through the generation of shear force that ruptures cell walls, and chemically, through the formation of free radicals that also attack cell membranes to cause cell death. Combining ultrasound and thermal treatments ("thermosonication") has proven to be an effective method for eliminating microorganisms. Researchers are looking into adding the antimicrobial peptide nisin to this method to see if it can prolong the shelf life of apple juice.

At a glance

Type	Nisin-assisted thermosonication
Year	2017
Key Feature	Antimicrobial, preservative
Current Application	Apple juice
Applicability	Fruit and vegetable juices
Main Limitation	Not enough testing done on taste

Technology

The treatment consists of adding a small quantity (50-200 ppm) of nisin in 100 mL of apple juice before putting the sample inside an ultrasonic processor with a water bath to control the temperature of the sample. The treatment was conducted at 52°C for 30 minutes. It was found that:

- The nisin and thermosonication combination decreased microbial activity significantly more than either individual method
- Juices treated with this combination had microbial levels low enough to still be safe for consumption after 15 days, while untreated juices would no longer be safe to drink

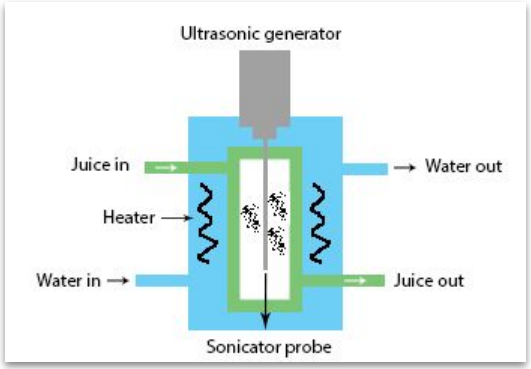


Figure: Schematic illustration of the thermosonication process.

Thermosonication of apple juice

Benefits

- The combination of methods (thermal, sonication, and nisin) was effective on a wider range of microbes than any one method alone
- Treatment conditions were mild and time required was relatively short (52°C, 30 min)
- Nutritional and visual values of the final product were not significantly altered
- This treatment has also been shown to work on products like carrot juice

Drawbacks

- Thermosonication has been shown to be more effective for acidic beverages (apple juice), so this may not be applicable to all types of beverages
- The effect of this treatment on the taste of the product has not been studied

Thermosonication has been tested with a number of different juices. However, this research shows added efficacy with the addition of antimicrobial peptides (nisin in this case) to the process, opening the door for further research and experimenting.

References
1. https://doi.org/10.1016/j.ultsonch.2017.11.020
2. https://doi.org/10.1016/j.tifs.2016.11.020

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