Final report

Review of Pressurised CO_2 technology (Farther Farms) and its ability to reduce reliance on a chilled supply chain - Literature Review

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Abstract

Farther Farms claim to have developed the first commercially available technology using supercritical fluids that enables the ambient storage of French fries, a product traditionally sold chilled or frozen. The start-up was founded in 2017 by Vipul Saran and Mike Annunziata who participated in the eLab accelerator program run by Cornell University. Vipul and Mike developed a patented technology that is now held by Cornell Centre of Technology Licensing (CTL), licensed to Farther Farms. Farther Farms is operating commercially through a pilot plant, based in Rochester, NY initially delivering ambient French fries into the QSR market with a shelf life of 120 days. The technology has been in development for the last four years and over the last year has garnered a sizable degree of coverage in the global press.

The first stage review process consisted of a literature review and inclusion of information from earlier face-to-face interviews with a co-founder and their senior team. Based on their opinion, the technology and principles are transferable across a wider range of food groups inclusive of red meat. Although there is a lack of scientific information available for its application or potential application for Red meat at this stage of the investigation, we are impressed by the energy and focus of the Farther Farm's team alongside the range of potentially disruptive benefits that the technology could deliver should its development and commercialisation successfully move from potatoes into other foods such as red meat.

It is our opinion, based on the review, that the momentum that Farther Farms is gaining and the ongoing interest from major French fries' producers the technology has potential to contribute to the MLA 2030 Strategic growth objective by its highly relevant application to red meat. However, transitioning the current application to Red meat would require a detailed food safety assessment, potential regulatory review, consumer acceptance testing and a detailed feasibility study to ensure the benefits are achievable and captured.

MLA commissioned Prof. Consulting Group to investigate more about the process, its claims and offer insights with recommendations as to how Farther Farms could be of benefit to the Australian red meat industry. This is our final report of findings resulting from a literature review and previous direct dealings with the Farther Farms inventors themselves. Recommendations are suggested for strategic alignment and commencement of Red meat research to enable the MLA to facilitate the introduction of new technology that could position the Australian Red meat industry at the forefront of a possible game changing technology for the global meat industry. Potentially opening access to new markets, eliminating the need for cold chain storage and logistics and reducing food waste.

Executive summary

Background

With the strategic objective of the MLA to double the value of Australian red meat by 2030, it is critical to keep abreast of new and emerging technologies that have the potential to unlock access to new high value markets for 'fresh' meat. Effective horizon scanning enables the MLA to capitalise and invest in high potential areas of innovation and development to deliver strong commercial outcomes with industry partners.

Recognising the significant cost of operating a chilled supply chain and reaching high potential global markets such as the Middle East and Europe, the initial claims associated with this technology potentially offer a solution to this challenge. The MLA commissioned Prof. Consulting Group to investigate Farther Farms' Pressurised CO_2 Technology and recommend how it could be of benefit to the Australian red meat industry.

This is our report of findings resulting from a literature review and previous direct dealings with the Farther Farms inventors themselves.

Objectives

The project successfully fulfilled its objectives:

- Summary of the science behind the technology and guidance as to whether the technology could meet its claims.
- Details on the progress of the innovation so far and a summary of the potential benefits and applications for the red meat industry.
- Recommendations for future engagement with the Farther Farms technology.

Methodology

Desk literature review complemented by previous face to face Zoom calls with the inventors and dialogue with the Farther Farms team.

Results and key findings

- Food tech start-up Farther Farms founded by Vipul Saran and Mike Annunziata has progressed Pressurised fluid technology to a commercial facility delivering their first product group, French fries, with 120 days ambient storage life marketed by Endico Potatoes and available at outlets such as Luna Inspired Street Food in Ithaca, The Hideaway and Radio Social, in Rochester NY.
- With the product commercially available and investment in capabilities underway, its potential to contribute to the future growth of Red meat is encouraging.
- Farther Farms have demonstrated in a short timeframe the ability to raise significant capital and commercialise the technology. Business partnerships with the likes of a former senior executive from the frozen food industry and a major local frozen food distributor illustrate growing confidence in its current direction.

- The product features and benefits cited by the inventors for application on potato French fries such as improved product quality, convenience and extended shelf-life without the chill chain requirements are compelling and in line with customer product and industry trends.
- In the absence of direct trials on Red meat, the technology would need to undergo design and development work for this application supported by expected product validations (microbiology validations of product and process and organoleptic test validations) to further determine its potential.
- The literature review has further identified multiple processing techniques that suggest pasteurisation or sterilisation capabilities of the technology. The benefits of either option clearly differing from extended chilled life to ambient storage capabilities. Either process requiring a different validation protocol when looking at Red meat applications.

Potential benefits to industry

- The ability to compete successfully in far-reaching markets with an Australian Red meat offer through extended life
- Disruptive and differential offers to access new markets
- Reduced carbon impact during Red meat distribution and ability to access more cost-effective supply chains
- Improved ESG (Environmental, Sustainable, and Governance) messaging versus competitors enhancing industry reputations
- Farther Farms has the potential based on its current commercial application within the French fries' supply chain to deliver a ‘fresh’ product without the need for a chilled supply chain through its sterilisation process, or extended life through its pasteurisation technology.
- Early involvement in the development and application of the technology, exploring its ability to deliver a safe and consumer suitable application with Red Meat, could position the Australian Red meat sector as a pioneering, progressive force, increasing commercial competitiveness in export markets.

Future research and recommendations

Prof. Consulting Group recommends further involvement with the team at Farther farms to stay at the forefront of this technological advance. Recommendations are suggested for Australian partnership and further research to support the Australian Red meat industry in the event that the technology delivers benefits via either the pasteurisation or sterilisation capabilities. As a well-funded technology, it has the potential to help access new markets, improve competitiveness and reduce food waste alongside lower storage and distribution costs.

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1.0 Background

MLA commissioned Prof. Consulting Group to conduct an investigative review of a food processing technology referred to as Pressurised CO_2, patented by Farther Farms, that claims to deliver a shelf-life extension whilst removing the reliance on a chilled supply chain. Its current application keeps French fries for up to 120 days without the need for refrigeration or the use of preservatives, and has recently scaled to operate commercially to supply a NY based QSR. The Pressurised CO_2 application is operated under patent by USA based company, Farther Farms.

As a new application of the technology in development for French fries processing, little is known about Farther Farms outside of its own marketing press releases. Encouragingly, it's important to note that with the commercial application underway, the Farther Farms senior leadership team are actively promoting the technology. The project investigated details of the process, benefits of the technology, understanding of the project status, business model, and the degree to which its marketing claims could be substantiated. This report concludes with guidance to the question of whether MLA should proceed with further investigation and engagement with Farther Farms.

Recognising the significant differences between the product groups of French fries and Red meat, most notably in micro loading, target micro-organisms, consumer expectation on taste, flavour, and cooking methods, the technology would require extensive trialling under a meat specific protocol for validation.

In our interviews with the founders, it was indicated that MLA was the first industry body representative to show formal interest in its application for Red meat; this report is the first to be commissioned by an Australian business entity.

Here follows a summary of findings, conclusions and recommendations meeting the requirements of the final report milestone of the Farther Farms research brief.

2.0 Objectives

The basis or reason for the project was knowledge, adoption and capacity building.

The original objectives of the project are shown below, as well as their success in meeting criteria and any additional clarifying comments.

Objective	Met successfully or clarifying comments
A comprehensive scientific based literature review on the technology.	Yes - Section 4
Benefits overview for the Red meat industry.	Yes - Sections 4, 5, 6
Supply chain applications and recommendations have been identified.	Yes - Sections 4, 6

Will this technology work, does it support the initial shelf-life claims, and is it worth the additional investigation? Technology can satisfy domestic and international food regulations.	Informed view provided across both potential applications pasteurisation and sterilisation however, technology for Red meat is untested.
Farther Farms business model has been identified and suitability for further engagement with trials recommended with Australian processors/manufacturers	Yes
Interested local partners have been identified as potential candidates for the next phase of technology testing.	Interested parties for approach have been identified as potential candidates.
Product and process validation and testing: assessment of product from pressurised CO_2 processing to determine customer acceptability and understand breadth of application.	Informed view provided; however, technology is still to undergo designed and validated trialling.
Some initial commercial viability assessments. Develop understanding of process implementation within the local marketplace.	Initial toll process insights provided of its current application.

Supporting commentary: the original research questions were structured recognising the impressive progress made with French fries and the consideration on its application for Australian Red meat. Whilst the founders were complimented by the interest shown by the MLA, they informed Prof Consulting Group their immediate focus is on growth in French fries and increasing capability. This review meets the objective of reviewing the technology as it stands today, from current available sources and through private direct discussions with the founders themselves.

3.0 Methodology

This report is the findings of desk literature review, Zoom face-to-face interviews with the founders themselves, compiled with interpretation and insights made by Prof Consulting Group's Founder, Mark Field.

The face-to-face interviews and direct interaction provided valuable access and a unique opportunity to dig deeper into claims and underlying science over and above the information generally available in the public domain. This provided insights about how the process works, the business model and plans for commercialisation. We have compiled an understanding of the process based on scientific desk research, published marketing releases, patent information and notes from the Zoom calls. Our connection with the founders was also a good platform to introduce MLA as a thought leader and potential interested party should MLA proceed to the next stages of engagement and investigation.

4.0 Results and Findings

4.1 Farther Farms and pressurised CO_2 technology

The company Farther Farms specialises in technology delivered via Supercritical fluids, allowing some food groups that are traditionally stored chilled or frozen to be stored at room temperature.

The currently commercially available product, French fries, was originally launched with an ambient shelf life of 90 days and has recently been extended to 120 days. Details as to how shelf life has been determined or its limiting factor were not available during this work. Farther Farms has been in development since 2017 and over the last two years has attracted significant interest within the US food industry as an exciting novel food processing technology.

The technology is currently operating commercially in Rochester, NY via a facility producing French fries for the QSR industry at present. There is a longer-term business objective targeting the French fries' supply chain in India, where the challenges of chilled supply chains and the cost of serving that market has been identified as a commercial opportunity for Farther Farms.

Vipul Saran, co-founder and Chief Technology Officer said, "by reducing dependency on the cold chain, we are leapfrogging a major limitation and creating new global opportunities. The sustainable, CO_2-based technology we've developed at Farther Farms is already taking French fries farther than they've ever gone before – and we're gearing up to do the same for foods across the spectrum."[1]

What is "Supercritical"?

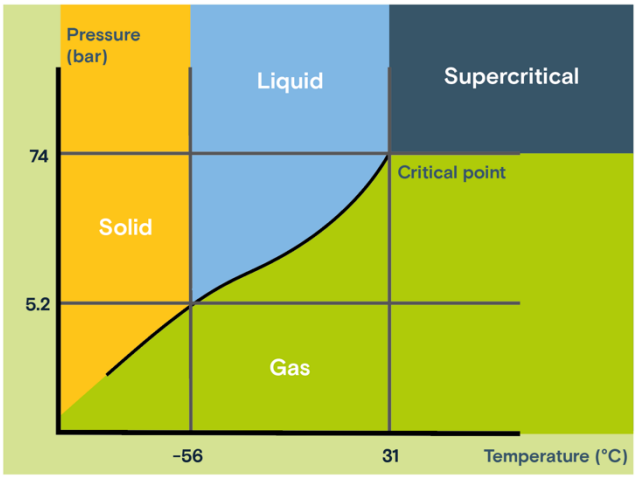
Any substance that is characterised by a critical point which is obtained at specific conditions of pressure and temperature. When a compound is subjected to a pressure and a temperature higher than its critical point, the fluid is said to be supercritical.

In the supercritical region, the fluid exhibits particular properties and has an intermediate behaviour between that of a liquid and a gas. In particular, supercritical fluids (SCFs) possess liquid-like densities, gas-like viscosities and diffuses intermediate to that of a liquid and a gas.
The fluid is referred to as supercritical when it is heated above its critical temperature and compressed above its critical pressure.

This particular behaviour of substances was first observed in 1822 by French engineer and physicist, Charles Cagniard de La Tour in his famous cannon barrel experiment. It was then defined as supercritical fluid by Irish chemist, Thomas Andrews. The most widely used supercritical fluids are CO_2 and water.

As shown on the phase diagram, the gas-liquid equilibrium curve is interrupted at the critical point, providing a continuum of Physico chemical properties.

[1] Https://www.freshplaza.com/article/9318919/father-farms-creates-new-french-fry-to-make-food-go-farther



Source: Author created adaption from Le Portal Des Fluides Supercritques

What is Supercritical CO_2?

Carbon dioxide (CO_2) is the most widely used supercritical fluid. This is because CO_2 is chemically inert, non-toxic, non-flammable and readily available at high purities and at low costs. The critical point of CO_2 is easily accessible (critical temperature 31°C and critical pressure 74 bar) allowing the fluid to be used at temperatures (35-130°C) without leaving harmful organic residues. Due to its interesting properties, supercritical CO_2 can be described as a "green" solvent.[2]

4.1.1 Company background and pressurised CO_2 gas patented technology

The start-up was founded in 2017 by Vipul Saran and Mike Annunziata who participated in the eLab accelerator program run by Cornell University. Vipul and Mike developed a patented technology that is now held by Cornell Centre of Technology Licensing (CTL), licensed to Farther Farms. Farther Farms is operating commercially through a pilot plant, based in Rochester, NY, delivering ambient French fries to the QSR market with a shelf life of 120 days. The technology has been in development for the last four years and over the last year has garnered a sizable degree of coverage in the global press.

The company has two patents on the technology, both filed in 2019. The patents were registered in 2017 and 2018. This includes technologies related to processing, packaging, and analytics. The patents are referenced below.

Process for improving shelf life of fresh cut vegetables and food products
The present disclosure relates to, inter alia, processes for improving shelf life and flavouring of fresh cut/fresh vegetables, as well as food products produced by these processes.[3]

Shelf stable potato product
A shelf stable potato/sweet potato French fry packaged in a hermetically sealed flexible bag/pouch.[4]

[2] http://www.supercriticalfluid.org/Supercritical-fluids.146.0.html
[3] https://patents.google.com/patent/US20190166859A1/en?inventor=vipul+saran&oq=vipul+saran
[4] https://patents.google.com/patent/AU2019351922A1/en?inventor=vipul+saran&oq=vipul+saran

4.1.2 Company funding and industry interest

As a start-up, the business completed its first significant capital raise through VC funding, raising USD $12m whilst growing their team in 2 years from 3 to over 25 people. Noticeably building a strong structure, Farther Farms have invested in core skills across food technology and process engineering.[5]

Since start-up, Farther Farms technology has been recognised by a number of leading food industry bodies including a Phase 1 research grant from the National Science Foundation as well as securing seed funding as part of the incubation programme. If you would like to read more, references are provided below:

- National Science Foundation[6]
- eLab[7]
- Cornell Center for Technology licensing[8]
- Rev: Ithaca Start up works[9]

4.1.3 Farther Farms partnerships, plant and scale up

Industry networks and support for future growth

Farther Farms is working with a number of well-regarded industry partners in the French fry industry and QSR, however at this stage they do not currently have equal expertise across Red meat, most likely due to their current strategic focus and short-term growth plans. In addition to their current business model the www site references their potential ability process other food groups including Red meat.

Current facility and plans for next stage

The facility in Rochester, NY is operational commercially and is supplying the local area. The business recognises the support it has had from Wegmans, one of the leading USA based retailers and claims to have served over 50 000 portions of French fries to 14 states and 5 countries. The founders have a documented strategy to supply French fries into the Indian market.
During our discussions with the founders, it was discovered that due to the rate of business growth they have not yet focused on the Red meat sector or the opportunity, although they are confident that the technology is transferable. This is also supported by some of the media interviews and the company website.[10]

Processing costs

One of the biggest hurdles to the technology going mainstream is the current cost of application and research. The current costing model is compared to frozen potato chips which are traditionally low

[5] https://news.cornell.edu/stories/2021/05/startups-sustainable-tech-takes-food-farther
[6] https://www.nsf.gov
[7] https://www.elabstartup.com
[8] https://ctl.cornell.edu
[9] https://www.revithaca.com
[10] https://www.fartherfarms.com/tech

cost to produce and distribute. The commercial robustness of an extended shelf-life product or an ambient product compared to traditional Red meat retail packs air freighted into the UAE, for example, would be expected to be considerably more favourable.

It is reported that the current cost of production is high, based on initial research and development costs with the existing product (shoestring fries) costing AUD$ 54 for 30lbs versus traditional frozen fries costing AUD$27-$40 for a 30lbs case.[11]

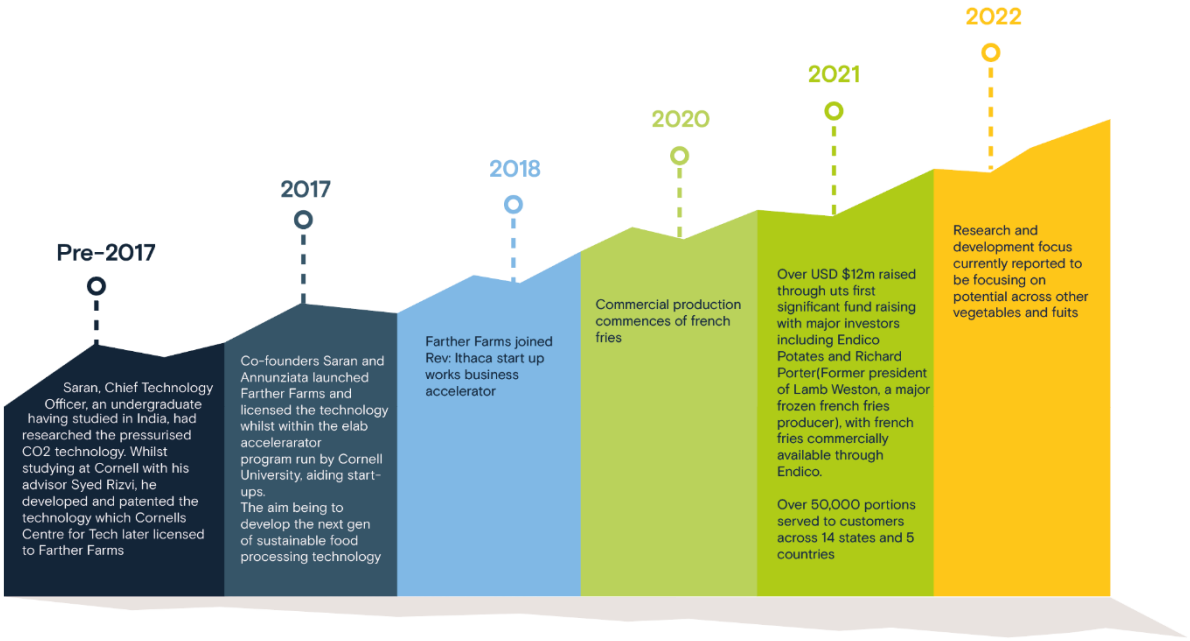
Customer acceptance challenges

An essential consideration for a successful launch of the Pressurised CO_2 technology will be the Go-to-Market strategy and selection on which process to develop through the technology, pasteurisation (extended life through a chilled supply chain) or sterilisation (access to extended life and ambient supply chains). There is the potential to create value at different stages of the supply chain, these include Food Service, further processing or manufacturing where the product would undergo changes such as cooking before being visual to the consumer. Additional considerations could be ambient storage and chilled display when retailing as this is where consumers expect to find meat. The GTM strategy will greatly influence the need for consumer education.

A focus on education and the encouragement of product trials so that consumers can experience the product quality will help to build consumer confidence in the new take on meat. This is applicable for a Retail, Business to Business (B2B) or Direct to Customer (D2C) strategy. Whilst in principle the technology is suited to other foods such as fruit, vegetables, dairy, and meat – Farther Farms have not yet focused resource on the opportunities available with Red meat.

4.1.4 Milestone's summary

Summary of key company and technology development milestones to date:



Source: Author created

[11]https://www.greenbiz.com/article/overcoming-cold-chain-isnt-small-potatoes

4.2 Farther Farms and pressurised CO_2 features & benefits overview

4.2.1 Farther Farms - cited product features

- Within QSR and HoReCa trades, reduces the requirements on significant frozen food storage capacity, reducing back of house space requirements and enabling more customer dedicated space. Potentially improving ROI for the growing number of fast-food outlets.
- Shelf-stable food products that require no refrigeration during storage and transportation and will not spoil when stored at room temperature for 120 days
- Technology transferrable across foods such as meat, vegetables, fruits, and dairy
- Technology applicable across solids, semi solids and liquid product categories
- Improves the texture, flavour, and nutritional values of processed food due to lower temperature processing capability
- The combination of high-pressure carbon dioxide and moderate pressure inactivates enzymes associated with 'Browning' and micro-organisms that cause spoilage.

4.2.2 Farther Farms - product benefits for French fries

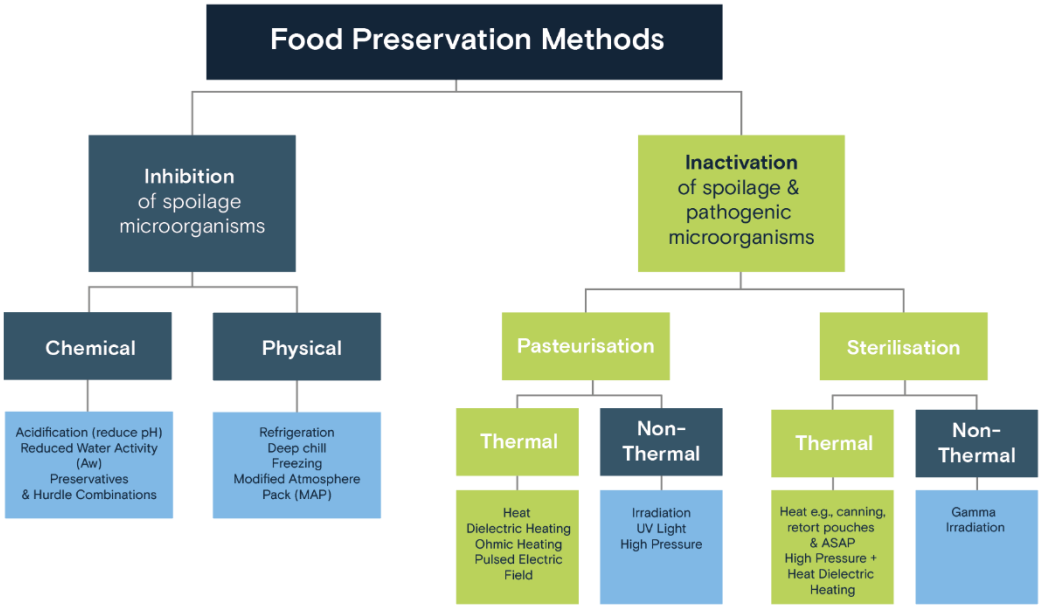
Quality & safety	· Superior quality ambient products based on less harsh processing techniques · Reduce food spoilage risk from temperature abuse · Reduce food safety risks through inactivation of micro-organisms
Reduced Costs	· No refrigeration costs - reduced costs of storage and distribution · Greater market access with easier shipping to markets and lower cost shipping · Ability to reach more distant markets with 'fresh' products · Decouples traditional chilled supply chains moving towards supply chain solutions currently not accessible for chilled products · May allow for longer, less frequent production runs - economies of scale
Convenience	· Reducing requirements for frozen or chilled storage areas · Quality advanced convenience e.g., better quality options for camping, rations, on-the-go · Supports growth of online deliveries / meal kits as products could be sent through post · Convenience and accessibility of canned food with the eating quality of fresh meat
Supply and access	· Support access to new markets that lack infrastructure or amenity to the chill chain · Support growth of direct online sales · Mitigate against risks of disruption in the supply chain, reduce waste · Reduce reliance on chilled chains · Product could potentially be transported ambient and retailed chilled to build consumer confidence and acceptance

4.3 Farther Farms technology and process details

Consumers have become accustomed to food preservation through technology and ingredients, reflected across the wide range of internationally sourced foods available in Australian supermarkets and independent grocers. Canned meats, modified atmosphere and vacuum-packaged meats, fermented and brined smallgoods, cook-chill meals, and sous vide meats are a few examples.

Food spoilage may be inhibited through chemical means by use of preservatives, drying of foods or physical methods such as high temperature treatment. Other products may receive a treatment to inactivate the present microflora such as pasteurisation of milk or cook chill methods to produce meals. A taxonomy of methods is summarised below, with Supercritical gas and similar technologies highlighted in green.

Farther Farms technology uses CO_2 for food pasteurisation similar to that applied to the well-recognised processes used for milk with hot water and steam, using High Temperature Short-time (HTST) at 75°C for 15 seconds[12]. This technology utilises the supercritical phase of CO_2 where the molecule is both a gas and a liquid at the same time. With the process delivered under pressure, lower temperatures can be applied which minimises the texture or visual change in the product. Recognising that pasteurisation is a combination of time and temperature ranging from 63°C to 115°C applicable across multiple food groups and pH ranges. The technology can also be delivered on a sealed product with the aim of delivering sterilisation.



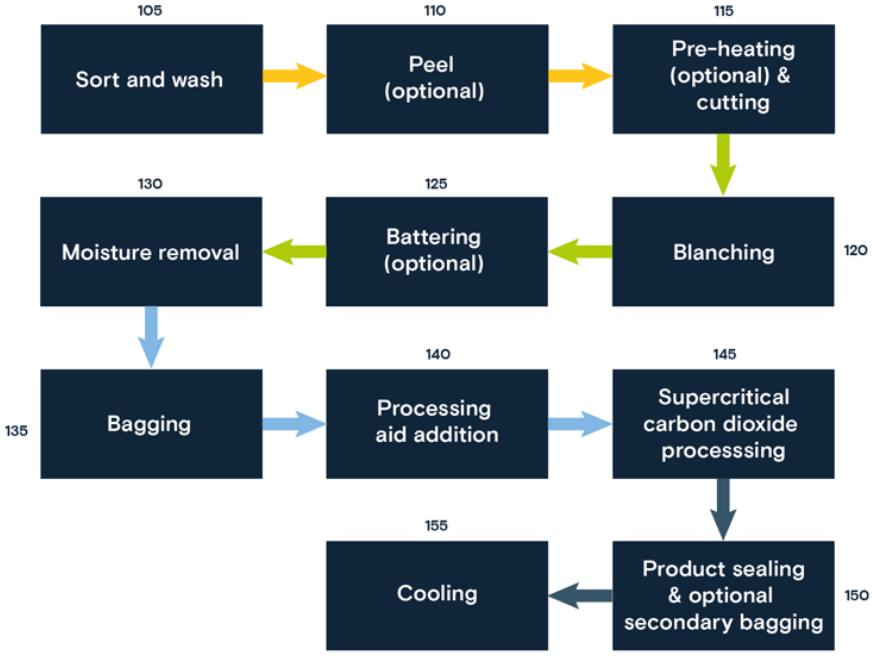
Source: Author adaptation of Koutchma (2011)[13]

[12] https://www.foodstandards.gov.au/code/proposals/documents/Scientific%20Evaluation.pdf
[13] Koutchma, T. (2011) *Novel Food Processing Technologies: Emerging Applications, Research and Regulations* Guelph Food Research Center

4.3.1 Farther Farms product components and pressurised CO_2 processing

Reviewing the patents, the technology can be applied to exposed and semi sealed products which the literature suggests would be a pasteurisation process, it can also be applied to sealed products which would warrant assessment for sterilisation as the two processing methods have different commercial advantages. Within the current commercial application, the technology is applied post the packaging stage of the process, where the French fries are bagged in a proprietary packaging material as a bulk product (not sealed), placed on metal racks at an individual layer and loaded into a chamber for processing in a batch application. Once processed the product appears 'vacuum packed' although the fries have retained their characteristic shape. The bags are then heat sealed. Post treatment product is boxed and ready for distribution at ambient.

An example of one of Process Flows



Source: Author adaption of Process from the patent[14]

Key points from the process flow

- Product is placed in unsealed bag with the open edge unobstructed on wire racks
- Blanching influences the cell structure and aids removal of moisture during processing and is optional within the current process design
- The bags used are vacuum packed style but have a proprietary design
- Once product treated bags are heat sealed
- Alleviating the blanching process, the flow of the process could work within a meat packing process flow i.e., treatment and then bag sealing for storage
- The patent also includes the ability to process unpackaged product prior to bagging with direct product treatment, and also the ability to treat fully sealed products
- Reduced cooking time claimed for fries at a lower temperature based on processing

[14] https://patents.google.com/patent/US20190166859A1/en?inventor=vipul+saran&oq=vipul+saran

How the process works based on the patent

The patent details multiple variations of the application, the process below is an indication of the key parameters for illustrative purposes

- Product blanched – increasing cell structure permeability enhanced for accelerated moisture removal by the Supercritical fluids
- Exposure to the Supercritical fluids with a processing aid (flavour) removing the first percentage of moisture whilst supporting the uptake of the flavour (infusion)
- Second exposure to supercritical fluid removing the second percentage of moisture, without the processing aid and delivers the shelf-life extension

It appears that that the water activity reduction and the pH change through the addition of flavour are an essential factor in the current shelf-life performance and product functionality. This would warrant further investigation when designing a Red meat focused trial. The patent refers to 4 potential processing methods, with the one described being the current commercial application. Flavour and blanching are not suggested as being essential in the success of the technology through its other methods of application.

Interpreting the patent, it suggests that the application of the processing aid which whilst adding flavour, also helps reduce the pH of the finished product to 4.6 or below which contributes to the shelf-life performance and the inhibition of micro-organism growth. The lower moisture content then claiming a reduced cooking time and >30% reduction in oil uptake when fried in oil.

If this process flow is transferrable to Red meat, it further opens possible innovation opportunities for enhanced flavour, reduced cooking times and improving consumer experience.

4.3.2 How Farther Farms technology claims to differ from other preservation methods

In the French fries process they claim to achieve commercial pasteurisation of foods by using a combination of proprietary packaging and gentler processing temperatures achievable due to the use of supercritical gas in preference to other traditional pasteurisation methods to reduce impacts on quality.

Summary comparison of perceived advantages between Farther Farms technology across a range of conventional food preservation methods based on its current commercial application.

Canned or retort food products	· Farther Farms - technology applies to multiple surface areas · Claim treated food products have texture, flavour, moistness, and nutritional values that are superior to canned and retort food products.
Frozen or Chilled food products	Farther Farms - does not require low-temperature cold chain management and in-home/in business equipment for storage on its current application

Sous vide food products	Farther Farms - current commercial technology delivers a pasteurised product not a sterilised product, current shelf life at ambient is 120 days with no data to compare for Red meat. (The patent includes a potential sterilisation application)
UHT aseptic processing	Farther Farms - claim to be suited to applications across solids, semi-solids and liquid products

4.3.3 Shelf life microbiological and organoleptic testing

Organoleptic quality assessments

At the time of the investigation, Farther Farms confirmed that they have so far only focused on success with fries and that customer feedback has been very positive.[15]

In the event that the technology is trialled on Red meat, an in-depth process design and validation programme would be strongly recommended, including customer acceptance. For example, changes in moisture could impact eating quality, visual appearance or increase likelihood of oxidative rancidity.

4.3.4 Will the technology work from a microbiological perspective?

Microbiological & chemical assessments

With the patent having variations on the process listed this is separated into 2 responses

Pasteurisation: its current application appears to be a pasteurisation process delivering shelf-life extension supported by reduced water activity and lowering the pH.

Sterilisation: is the second application with the patent, where applied through a sealed bag and targeting a sterile product protected from external recontamination, if successful would support access to the ambient supply chain.

The technology may have the potential to work from a microbiological perspective across Red meat, although work is needed to deliver a more robust hypothesis. It is essential to design a roadmap towards a commercial application and business case, and important to target one application of the technology to support a robust validation and process design.

[15] https://www.fartherfarms.com/fries

From a microbiological risk assessment perspective, the pasteurisation is recognised as an effective intervention in extending product shelf life which would require chilled storage. Dependent on the achieving adequate temperature and times values for Red meat, it could theoretically be sufficient to pasteurise the product.

The target pathogenic micro-organism of most concern for the process is *Clostridium Botulinum* due to its resistance to heat, as well as its ability to form spores and release deadly neurotoxins.

Greater visibility of the process and key controls are needed to independently underwrite the validity of the technology to meet its claims:

- Target process - pasteurisation or sterilisation?
- The product time / temperature equation would be critical
- Validation and verification of the process's effectiveness on Red meat is required
- Spores of *C. botulinum*, *Bacillu*s spp and thermophiles would need to be proven to be fully inactivated if this product was to be stored at ambient temperature.

4.3.5 Farther Farms technology readiness level

- Commercially available with over 50 000 portions of fries consumed and international sales, still to be proven in Red meat
- Technology readiness based on French Fries level 9 of 9 (TRLS)
- Technology readiness based on Red meat application level 1 of 9 (TRLS)

A TRL scale is helpful when considering where Farther Farms is in its readiness, both for French fries and Red meat applications as a comparison. Technology readiness levels, developed by NASA, is a scale that can be used for estimating the maturity of a given technology for market.[16]

TRL 1 is the lowest, indicating the earliest stage of development for a new technology, and TRL 9 is the highest, indicating the technology is fully implemented commercially. The scale is used across industries such as auto, biotechnology and food. There are nine levels, which each represent a stage in the development of technology, from the first thoughts to the final technology.

Farther Farms is well advanced and running commercially with its readiness in French fries' production, and we rate it at ‘Basic Principles Observed’ as TRL stage 1 for Red meat.

[16] NASA (2010). Technology Readiness Levels Demystified.
https://www.nasa.gov/topics/aeronautics/features/trl_demystified.html

French Fries	Red Meat	
TRL 1 Basic principles observed	**TRL 1** Basic principles observed	· Identification of new concepts and its integration, expected barriers, and applications. · Identification of materials and technologies based on theory. · Evaluation of potential benefits of the new concept over existing ones.
TRL 2 Technology concept formulated	**TRL 2** Technology concept formulated	· Enhanced knowledge on technologies, materials, and interfaces. · New concept is investigated and refined. First evaluation about the feasibility. · Initial numerical knowledge. Qualitative description of interactions between technologies. · Prototyping approach and preliminary technical specifications for laboratory test are defined.
TRL 3 Experimental proof of concept	**TRL 3** Experimental proof of concept	· First laboratory scale prototype or numerical model. · Laboratory tests of the technological element, but not the whole integrated system. · Identification of key parameters characterising the technology. · Verification of the proof of concept through simulation tools and cross-validation with literature data
TRL 4 Technology validated in lab	**TRL 4** Technology validated in lab	· Small-scale prototype integrated with complementing subsystems at laboratory level. · Validation of the new technology through enhanced numerical analysis (if applicable). · Measurable Key Performance Indicators. · Prototype shows stable performance (either TRL4 or TRL5, depending on the technology)
TRL 5 Technology validated in relevant environment	**TRL 5** Technology validated in relevant environment	· Large scale prototype integrated with components of supporting elements and auxiliaries. · Robustness is proven in relevant working environments. Prototype shows stable performance · The process is reliable, and performances live up to expectations · Other parameters concerning scale-up, environmental, regulatory, and socio-economic issues are defined and qualitatively assessed.
TRL 6 Technology pilot demonstrated in relevant environment	**TRL 6** Technology pilot demonstrated in relevant environment	· Demonstration of the technology is fine-tuned to a variety of operating conditions in relevant environment. · The process is reliable, and the performances live up to the expectations · Demonstration of interoperability with other connected technologies. · Manufacturing approach is defined (either TRL6 or TRL7, depending on the technology). · Environmental, regulatory, and socio-economic issues are addressed.
TRL 7 System prototype demonstrated in operational environment	**TRL 7** System prototype demonstrated in operational environment	· Full scale pre-commercial system is demonstrated in an operational environment. · Compliance with relevant environment conditions, authorisation issues, local/national standards is guaranteed. · Integration of upstream and downstream technologies are verified and validated. · Manufacturing approach is defined (either TRL6 or TRL7, depending on the technology).
TRL 8	**TRL 8**	· Technology has been experimented in deployment conditions and proven its functioning in its final form.

System complete and qualified	System complete and qualified	· Manufacturing process is stable enough for a low-rate production. · Training and maintenance documentation are completed. · Integration at system level is completed. Full compliance with obligations, certifications, and standards of the addressed markets.
TRL 9 System proven in operational environment	**TRL 9** System proven in operational environment	· Technology proven fully operational and ready to be commercialised. · Full production chain is in place and all materials are available. · System optimised for full rate production.

Adapted from TRL scale: s3Food[17]

Whilst scoring well for French fries, the lack of development in Red meat application to date scores low. As found during discussions with the founders, this isn't due to the technology failing or not being translatable to Red meat, it is driven by the effort and energy they have put into delivering a commercially available technology targeting a specific product category and the lack of current activity targeting Red meat. It would be reasonable to conclude that partnering with a well-equipped meat processor with Farther Farms scientific expertise and some robust preliminary Red meat design the TRL process could be fast tracked to deliver an outcome for Red meat.

Robust process design verification and management is critical to safeguard the process and its delivery. Partnership support from global leaders in the areas of Red meat, packaging and food science will increase the likelihood of success

4.3.6 Does the technology meet regulatory requirements?

Assessed as being at TRL 1, the technology has not progressed far enough to meet regulatory requirements such as FDA (US) approval or Australian New Zealand Food Standard Code requirements for Red meat it would also be dependent on the application being pasteurisation or sterilisation. However, at TRL 9 for French fries and commercial trading in the USA with export into five countries gives a strong indication on its ability to meet regulatory requirements.

[17] https://s3food.eu/technology-readiness-levels/

4.4 Market opportunities in Australia

4.4.1 Target markets

Farther Farms technology could add significant value to the Australian Red meat industry if transferable across two areas.

Pasteurisation could offer extended shelf life on a product that appears visually close to traditional fresh meat. Whilst not achieving the ambient supply chain and extension of product life versus traditional Red meat would unlock access to new markets and commercial value.

Sterilisation as an application should facilitate access to the ambient supply chains and further extended product life which would remove significant costs from the supply chain and deliver a competitive advantage in a challenging market. Additionally, even a week's extra life on a retail product would support access to new markets. Successful adoption of the technology would benefit multiple customers and end users through accessing additional usage occasions.

The current marketing of the technology targets the product solutions for intermediate goods or semi-finished food products for use in hotels, restaurants, eateries, and food factories. It is not yet targeting a customer facing or retail offer.

Commercially pasteurised food products could be supplied to aviation, aerospace, disaster relief, hospital, and military applications as well as supermarket and online retailing.

There is also an opportunity to access new markets with ambient products due to lack of cold chain infrastructure and reduced distribution costs for the Sterilisation application.

4.4.2 What will customers think? Thoughts on mainstream retail acceptance.

More research into target market retail acceptance is recommended to understand customer thoughts and willingness to accept Farther farms technology as an alternative to fresh or ambient protein products. Some challenges may be overcome through product positioning, design, recipe and packaging. Similar challenges were certainly faced by UHT milk and ambient meals at a point in their evolution. Examples are shown below:

Ambient products in market place:

Source: Tata India Mats Technology[18]

[18] https://www.915labs.com/foods

Ambient food often suffers a poor-quality perception versus fresh despite sometimes possessing similar organoleptic qualities to their more perishable counterparts. To overcome this challenge some products are retailed from the fridge for enhanced freshness perception. To encourage initial trial, this may be a retail route consideration for Farther Farms.
Some examples are shown below:

Ambient / long life products sold from the chiller

Source: [19]

Source: [20]

4.5 The Commercial model for Farther Farms Partnerships

Currently, Farther Farms is taking their patented technology to market by operating as a further processor sourcing the raw potato and delivering the ambient French fries, as opposed to a toll manufacturer more commonly seen with high capital technologies such as High-Pressure Processing (HPP). Considering the economic benefits of accessing an ambient supply chain for traditionally chilled products it will be interesting how this model grows to support predicted demand as food supply chains change. Whilst there are no insights into how the business will evolve, a technology licensing agreement to gain market share and speed of uptake would be a reasonable approach.

4.6 Photo gallery

Finished product	**Finished product**
	
Source: Farther Farms Media Pack[21]	Source: Farther Farms Media Pack[22]

[19] https://www.eatfiid.com
[20] https://www.oatly.com/int/
[21] https://www.fartherfarms.com/tech
[22] https://www.fartherfarms.com/fries

Product process in the commercial facility	Processed product for distribution
	
Source: Farther Farms Media Pack[15]	Source: Farther Farms Media Pack[16]

5. Conclusion

Farther Farms is operating a patented technology that is commercially available for French fries, but has not yet been tested for Red meat. As a potential enabler for the Australian Red meat industry to be able to access an wider supply chain, new markets and increasing competitiveness in international markets further engagement and development is highly recommended. The technology has the ability to treat complex products with multiple surfaces which could offer wider applications across processed meats (i.e dice, mince, strips) straight cut portions and potentially Primal's.

If successfully transferable into Red meat and commercialised, Farther Farms is an exciting technological advance for food preservation delivering benefits in chilled life or access to ambient supply chains - presenting significant cost savings, quality and sustainability advantages over traditional food processing methods including canning, retorting, chilled and frozen foods.

The Go-to-Market strategy will be critical in educating consumers and end users of the product's safety and its benefits. It is an exciting and leading-edge technology with real commercial benefit to the primary Red meat sector and could benefit other food groups once commercially available.

5.1 Key findings

- The technology has several process capabilities within its patent that have the potential to add value through pasteurisation or sterilisation
- The technology being commercially available and operating in other areas of food production gives a degree of confidence and interest warranting ongoing engagement
- The level of funding achieved to date and quality of industry partnerships infers credibility of the technology
- The commercial product has been exported and over 50 000 cooked portions sold to consumers, supports the product quality claims around the current French fries capability
- The strengthening of capability with the Farther Farms team for future growth and innovation is noted

- The Australian Red meat industry has an opportunity with the MLA to lead the focus on Red meat and potential first to market advantage
- The lack of evidence to support its application in Red meat would require a detailed design to adoption program to ensure thorough and robust validation.

5.2 Benefits to industry

- The potential to remove significant costs from the supply chain increasing the competitiveness of Australian Red meat
- Removing the high cost of refrigerated supply chains and enhanced food safety controls should improve profitability of the Red meat industry and deliver the additional benefits of an important sustainability message via the sterilisation application
- Extension of product life via a chilled chain reducing waste via a pasteurised solution
- Adoption of the sterilisation technology could, subject to regulatory alignment, provide access to a global market for the Australian Red meat sector.
- Adoption of the pasteurisation technology could, subject to regulatory alignment, provide access to a new market for the Australian Red meat sector.
- Other market opportunities include a D2C model, where as an example, international consumers could subscribe to a regular butcher's box program of Australian steak.
- Industry leading messaging around improved environmental performance

6. Future research and recommendations

By further engagement with Farther farms and encouraging its focus on Red meat through its development and commercialisation programme we recommend the following further avenues of research and involvement:

Future R&D applications	· Jointly build a portfolio of scientific data with a recommended third-party review and verification by expert agencies such as CSIRO or Campden (UK). Both Internationally respected in the area of thermal process define, verification and third-party certification; (Campden have provided initial engagement as part of this review)
Practical Application	· Further engagement and defining a business model to make the technology available to the MLA and the Red meat industry. · Assess product here in Australia. · Highly recommend a trip(s) of interested parties to view the USA facility, extend engagement with founders, view the process and further try products. · Scoping proposal for Australian based pilot facility and industry partners. · Commence regulatory discussions around technology, its acceptance and timelines for process

Customer Insights	· Direct experience of consumer acceptance of products is essential, research is recommended to understand customer acceptability (both as shoppers and as Food Service end users) and obstacles to acceptance for each target customer segment.
Business Case Modelling Based on Next Stage	· More information needed to understand commercial viability of processes when tech development nears market completion. · NDA disclosure of commercial modelling to date recommended. · Model costs of chilled versus ambient supply chain into emerging markets to understand potential improvement in competitiveness. I.e. Could Australian Red Meat be 10% more competitive versus other exporters?

Suitability for further trials with Australian processors and manufacturers

MLA/Industry involvement is recommended now due to the perceived potential of Farther Farms to capitalise on being an early adopter and promoter with influence on its application and commercialisation. The benefits of accessing new export markets, reducing food waste and improving the cost and quality of existing product chains are potentially significant.

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