Final report

Preservation of Meat Products Utilising Flavour Symmetry Technology

Abstract

A dehydrated, raw, red meat product, shelf stable at ambient temperatures, that retains its original organoleptic characteristics on rehydration, would be a highly marketable product for the red meat industry in Australia.   The study assessed True Essence Foods' Flavour Symmetry™ (FS) technology, which utilizes low-temperature, molecularly selective dehydration, to create such a product.

Multiple cuts of raw beef were dehydrated to a water activity Aw below 0.6, which were then tested for microbial safety and reconstituted for sensory evaluation in various cooking applications. The dehydrated products were safe for human consumption and were shelf stable for up to two months in ambient storage. The products could be reconstituted by soaking in cold water for twenty minutes and retained the texture, colour, and flavour of beef, and were superior to alternative products like freeze dried beef, and in select applications, to a fresh meat counterpart in flavour and taste.

This exploratory study demonstrated that TEF FS technology produces a desirable, shelf stable dehydrated red meat product that could be distributed through an ambient supply chain. These products could expand market access and create a new, high value segment for the Australian meat and livestock industry.

Executive summary

Background

Raw fresh red meat products have a short shelf-life and requires a under 4oC cold chain supply system due to their high-water content and potential for spoilage due to microbial contamination and biochemical degradation. It has proven to be difficult to create a shelf stable raw meat product for use in different food applications, that can be stored in ambient conditions, which also retains its original organoleptic and textural properties. While freeze dried raw meat is currently available on the market as a shelf stable product, its taste, flavour and textural properties are significantly inferior to fresh meat.

True Essence Foods (TEF) has developed a proprietary, unique Flavour Symmetry™ (FS) System that enables accelerated dehydration at low temperatures to preserve fresh flavours, texture and nutritional composition. TEF's FS Technology can dehydrate material to the exact desired water activity by varying air flow, sample parameters, airflow temperature, and time to reduce water activity of foods to less than 0.1 without impacting their organoleptic profile. TEF has demonstrated the success of this technology with various shelf-stable raw ingredients such as animal, fruit, and vegetable-derived products.

A proof-of-concept study to validate the product concept, safety, shelf stability and organoleptic characteristics of TEF FS Technology processed red meat products will help define the product concept for future work.

Objectives

The primary objective of the study was to test if raw beef can be dehydrated to a shelf-stable state at ambient room temperature using proprietary TEF FS technology, as well as to evaluate whether the reconstituted red meat samples retained the organoleptic characteristics of the original meat product in different food applications.

The project demonstrated that:

- TEF FS technology can be used to dehydrate half-inch cubes, ground beef, and stir-fry strips to a water activity of less than 0.6, to form a pliable, dry product that reconstitutes by soaking in cold water and retains the organoleptic properties of the original raw meat in different cooking applications like patties, soups, Bolognese sauce and stir fry.
- Ground beef in a Bolognese sauce and stir fry strip applications provides a gourmet product with a rich, meaty flavour and surpasses freeze-dried meat products.
- The dehydrated products were shelf stable under ambient storage conditions for the 65-day trial period. The study was terminated at this period. Based on the results to date, longer storage times are likely to be attainable if the tests are carried on for a longer period of time.
- Larger cuts of meat took a longer time to dry and the ideal cuts for this application are ground beef (80:20 and 90:10) and stir-fry strips.
- TEF FS technology can be used to dehydrate ground beef and stir-fry strips to a water activity of less than 0.25 to form a crumbly powdered product that would be ideal for soup mixes and flavourings. This was not pursued further as the focus of the project was to make dehydrated products that retained the mouthfeel and texture of fresh red meat.

- A dehydrated red meat product produced using the TEF FS System could create a valuable new, shelf-stable, product that is elevated in taste and flavour to fresh meat and similar to it in texture, and that may be stored at room temperature and be transported through an ambient supply chain.

Methodology

A range of predetermined Flavour Symmetry™ process conditions were tested to produce optimal conditions for rapid mass reduction and organoleptic profile retention for the identified sample materials to a water activity below 0.6. Quantitative and qualitative tests were conducted by TEF upon each proposed sample material for safety, stability and organoleptic evaluation.

The materials tested were minced beef - 80:20 and 90:10, ¼ inch cubes (Sirloin Strip Steak), ½ inch cubes (Sirloin Strip Steak), 1-inch cubes (Sirloin Strip Steak), and Stir fry strips – 5cm x ½ cm (Eye of Round). Dehydrated samples were tested for food safety, microbial stability and reconstituted and tested in different food preparations for organoleptic evaluation of the different meat products.

Results/key findings

TEF successfully defined the optimal conditions for dehydration of the red meat samples and TEF and MLA finalized the process conditions and red meat cuts that would be used to produce bulk dehydrated samples for stability and organoleptic studies. The ground beef and stir-fry samples were optimal in this application and could be consistently dehydrated at low temperatures to a water activity below 0.6 within forty hours.

The dehydrated samples were safe for human consumption with microbial loads for standard pathogens tested for food safety within acceptable limits at ambient temperature storage for a period of up to 65 days.

Reconstitution tests with the ½ inch cube and ground beef processed products showed that soaking in cold water for 20 minutes, with no application of salt, provided the best results and this protocol was used for all other studies. The reconstitution test for Stir-fry strips included an additional test for a refrigerated soak in cold water for six (6) hours. This yielded a texture and chewiness similar to fresh meat and provided a highly desirable sensory experience with the final product. Refrigeration and soaking for up to 6 hours is recommended for future tests for all dehydrated products.

The cooking tests demonstrated that:
- Half-inch cubes in a soup application delivered a rich umami, beef flavour that was superior to the taste of fresh beef cubes and the freeze-dried cubes, which provided a very poor texture, flavour and taste experience. The TEF dehydrated beef cubes retained the fibrous structure and mouth feel of beef. Additional cooking time may result in a more tender meat and could be considered for additional studies.
- TEF-processed ground beef resulted in a Bolognese sauce with a more intense meaty flavour over fresh ground beef, while freeze dried ground beef resulted in an undesirable end product. Additional tests with a longer soak time are recommended for future studies with ground beef.
- TEF processed stir-fry soaked for six hours in a refrigerated environment resulted in a product with an outstanding, rich, deep beef flavour like aged meat with a texture like fresh meat with a slight chew. The team indicated that they kept going back for seconds. Sensory studies with TEF processed stir-fry soaked for twenty minutes in cold water resulted in a chewy product that was undesirable.

Benefits to industry

The study clearly demonstrated the potential to apply TEF FS Technology to make a new organoleptically superior, shelf stable, red meat product that can be used to reach markets that are currently limited in the use of raw red meat. Initially, a TEF-processed product would allow remote communities, campers, disaster relief and other situations that may lack refrigeration to have access to raw red meat for various food applications. The technology is easy to implement, and initial economics of the technology appear profitable.

Future research and recommendations

A larger scale, longer term study to better define dehydration parameters would be useful to define processing efficiencies that would help define manufacturing costs of the TEF FS technology. Collaboration with large scale processors would also be useful to define product handling parameters and develop a system for large scale industrial implementation.

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1. Background

Raw red meat products have a short shelf-life and require a cold chain supply system due to their high-water content and potential for spoilage due to microbial contamination and biochemical degradation. Fontana (2001, p. 1-5) and Chirife et al (1996, p. 465 – 500) have identified water activity as a key determinant of spoilage, as it is the main factor that influences microbial growth and subsequent food spoilage. The United States Department of Agriculture's Pathogen Modelling Program published the Division of Food Science and Technology Fact Sheet of CSIRO (1995, p.1) provides guidelines for food safety indicating water activity required for growth of food borne microbes and that dehydrating red meat products to a water activity below 0.6 could result in shelf-stable products at ambient conditions, once packaged appropriately.

Numerous methods have been developed over human history to cure and preserve red meats. The systems have led to many specialty products that use salt and heat to develop specialized red meat products, such as jerky, that are widely available. It has, however, been very difficult to create a raw meat product for use in different food applications that retains its original organoleptic and textural properties. While freeze dried raw meat is currently available on the market as a shelf stable product, its taste, flavour and textural properties are significantly inferior to fresh meat.

Nowak and Jakubczyk (2020) have described red meat freeze drying as a process that involves the freezing of meat products and then sublimation of water under vacuum followed by desorption at normal pressure for final drying. Loskota et al (2023) completed a review on the application of freeze drying in meat processing and describe it as an energy intensive and economically expensive process.

A comprehensive review of drying meat products and the associated effects and changes by Ahmed et al (2022) showed that higher temperatures during dehydration are correlated to lower product quality as a result of the breakdown of heat sensitive compounds such as proteins and vitamins, as well as a decline in colour quality and rehydration capacity. Kilic (2009, p. 173-180) also demonstrates that higher temperatures also increase the browning of the product and case hardening of the outer layers of the product resulting in a reduced rate of dehydration, particularly for thicker cuts. Lower temperature dehydration is the key to TEF's FS technology product quality as it prevents biochemical and structural degradation.

True Essence Foods (TEF) has developed a proprietary, unique Flavour Symmetry (FS) System that enables accelerated dehydration at low temperatures to preserve fresh flavours, texture and nutritional composition. TEF's FS Technology can dehydrate material to the exact desired water activity by varying air flow, material parameters, air flow temperature, and time to reduce water activity of foods to less than 0.1 without impacting their organoleptic profile. TEF has demonstrated the success of this technology with various shelf-stable raw ingredients such as animal, fruit, and vegetable derived products. True Essence Foods Flavor Symmetry technology is a fully-integrated, proprietary solution that protects the fingerprint of fresh flavor of products while eliminating the need for refrigeration and cold chain.

TEF FS uses a closed-loop air circulation system to control relative humidity and maintain a continuous, dry air flow over the product that pulls moisture from the product. The moist air is cycled over a desiccant that selectively absorbs water and returns all other volatile flavour molecules to the headspace for retention by the product. The system provides extremely dry air at low temperatures with low relative humidity that can pull moisture from product samples at very low temperatures. Low relative humidity allows the system to absorb more moisture from the product

without increasing the temperature. The process of moisture removal under low relative humidity and low temperature conditions is not linear, and the moisture transfer is not simultaneous. Moisture removal is largely product dependent, and water removal rates correlate with diffusion of water out of the product. Flavor Symmetry employs a unique molecular filter which separates and removes water at an atomic scale, keeping the flavor, aroma, and nutritional components of your product intact.

The following Diagram 1 describes the process and shows how it is different from freeze drying.

Diagram 1. Comparison of TEF Flavour Symmetry Technology to freeze drying.
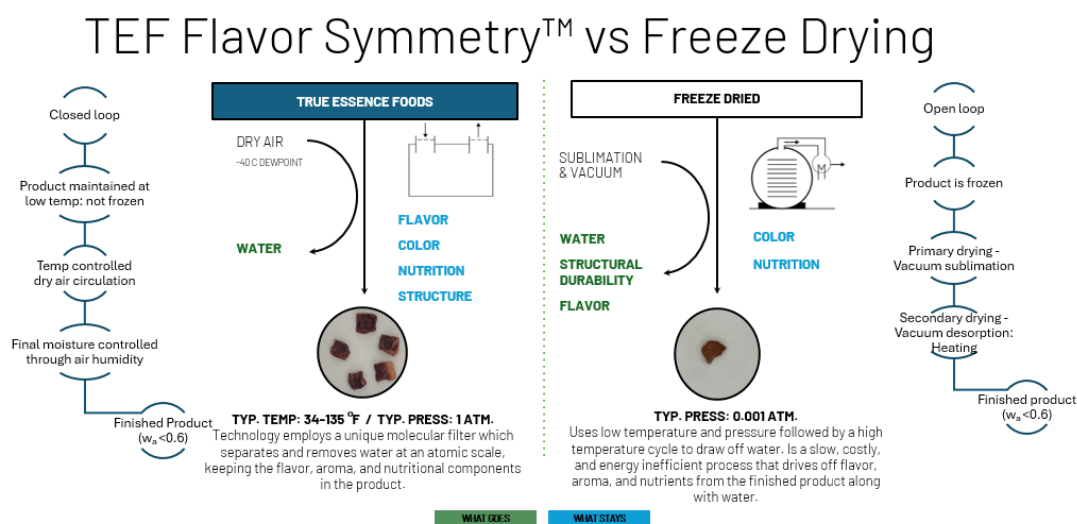
Given the attributes and problems with creating a shelf stable raw red meat product, TEF's FS technology has the unique potential to dehydrate raw red meat to a water activity level below 0.6 at low temperatures, while preserving its original organoleptic characteristics and texture. A feasibility project that can demonstrate this new product concept and its potential to create a novel, high value market segment for raw red meat products would be a first step to further engage meat and livestock producers and move this product concept to the market. This product segment could create a valuable new product segment for meat processors and help the meat and livestock industry expand the utilization of their produce.

A successful outcome of this feasibility project could lead to a larger scale, longer term project that would further validate the product concept. This would allow TEF to engage and work closely with industry partners to ensure that all future developments would be directly applicable to the industry that could be easily adopted and scaled up by the meat and livestock industry.

2. Objectives

2.1 Preservation of meat products utilising FS technology

The goal of the study was to dehydrate raw beef to a shelf-stable state with a water activity below 0.60 and then to evaluate the organoleptic characteristics of meat constituted from the processed shelf stable samples. All objectives of the project were completed on a timely basis.

2.1.1   Project Objectives

2.1.1.1   **Objective 1**

To dehydrate raw pieces of select cuts, cut to half inch cubes (Sirloin strip), under refrigerated conditions to a water activity, measured at 23 °C, of less than 0.60 and more than 0.40, resulting in a more shelf-stable pliable product.

2.1.1.2   **Objective 2**

To dehydrate raw pieces of select cuts, 5 cm x 1 cm stir fry strips (eye of round), under refrigerated conditions to a water activity, measured at 23 °C, of less than 0.25, resulting in a more shelf-stable, crisp product.

2.1.1.3   **Objective 3**

To dehydrate 90CL and 80CL minced beef under refrigerated conditions to a water activity, measured at 23 °C, of less than 0.60 and more than 0.40, resulting in a more shelf-stable, pliable product.

Original objectives 2, 4, and 6 which were aimed at dehydrating the above beef meat cuts to a water activity of 0.25 were set aside in lieu of running additional minced beef samples and exploring additional process conditions.

2.1.2   Updated Milestones

Based on the progress of the project and discussions between the TEF research and MLA project teams, the following revised milestones were proposed and completed for a successful conclusion of the project.

Milestone 1   Define Process Conditions
Dehydrate raw pieces of select cuts, cut to 25mm cubes (rump), minced or one-inch-thick whole steaks, under refrigerated conditions to a water activity, measured at 23 °C, of less than 0.60 and more than 0.40, resulting in a more shelf-stable pliable product and below 0.25 for a shelf-stable crispy product. Completed.

Milestone 2   Refine Process Conditions
To dehydrate raw pieces of select cuts, cut to ¼ inch, ½ inch and 1 inch cubes (Sirloin Strip Steaks), minced meat 80:20 and 90:10, and stir-fry strips (Eye of Round), under refrigerated conditions for the first 24 hours to a water activity, measured at 23 °C, of less than 0.60 and more than 0.40, resulting in a more shelf-stable pliable product and below 0.25 for a shelf-stable, crispy product. Completed.

Milestone 3   0.5-inch cubes studies
To dehydrate raw pieces of ½ inch cubes of Sirloin Strip Steak meat, under low temperature conditions until target water activity is achieved to a water activity, measured at 23 °C, of less than 0.60, resulting in a more shelf-stable, pliable product. The dehydrated samples to be reconstituted for organoleptic and stability testing. Completed

Milestone 4   90:10 and 80:20 minced meat and stir fry strip studies
To dehydrate of 90:10 and 80:20minced beef, from Strip/Sirloin Steak, under low temperature conditions until target water activity is achieved to a water activity, measured at 23 °C, of less than

0.60, resulting in a more shelf-stable, pliable product. The dehydrated samples to be reconstituted for organoleptic and stability testing. Completed.

Milestone 5   TEF to provide detailed flow chart of process that can be replicated at scale and reheating instructions and tasting SOP. Completed.

Milestone 6   Reheating Instructions and Tasting SOP. Provided in Milestone 4 Report

Milestone 7   Submission of Final Report to MLA. See this Report.

3. Methodology

3.1 Red meat TEF Flavour Symmetry™ Processed Samples

The intent of the present study was to dehydrate raw beef to a shelf-stable state with a water activity between 0.4 - 0.60 and below 0.25, that can be reconstituted into red meat products.

After Milestone 2 review, the project team decided to focus on meat products with water activity of 0.4-0.6 only. Products with a water activity of 0.25 became very brittle and were more suited to powdered applications, which are not the focus of this project. The focus of this project is to reconstitute red meat to be used as a replacement for fresh raw beef. Experiments related to the lower water activity products were discontinued.

Based on Milestone 1 and Milestone 2 results, the project team selected minced beef 80:20 and 90:10, ½ inch cubes, and 5cm x 1cm stir fry strips for dehydration, safety, stability and organoleptic testing. The teams decided to focus on ground beef, stir fry strips and ½ inch cubed beef cuts. Cuts larger than ½ inch cubes could not be dehydrated to a water activity below 0.6 after 13 days for steak and eight days for the one-inch cubes at the selected process conditions. While temperatures higher than 40 °C resulted in a reduction in water activity below 0.6, the colour and the texture of the final product was not deemed to be desirable.

A range of predetermined FS process conditions were tested to produce optimal conditions for rapid mass reduction and organoleptic profile retention for the identified sample materials to a water activity below 0.6. Quantitative and qualitative tests were conducted by TEF upon each proposed sample material for safety, stability and organoleptic evaluation. The following experimental protocols were developed to achieve the target.

3.1.1   Process conditions and product samples for stability and organoleptic studies

TEF tested numerous process conditions, consisting primarily of product size, temperature, air speed, and time for dehydrating red meat cuts to preserve the appearance and flavour while developing a shelf-stable, dehydrated product for storage and shipping. TEF initiated the project at temperatures outlined in the Project Statement of Work and supplemented them with additional process conditions after discussions with the MLA team.

Based on TEF experience with similar materials, the following product samples were tested in Experiment 1.
Product Samples:
- Minced beef, 90% lean:10% fat
- 25mm cubes beef bottom roast
- Whole Steak - 1-inch-thick boneless ribeye (scotch) beef fillet

Based on the drying time and product characteristics and discussions between MLA and TEF, the following product samples were selected for subsequent bulk dehydration studies under the project.

- Product Samples:
    - Minced beef (80:20)
    - Minced beef (90:10)
    - ½ inch cubes (Sirloin Strip Steak)
    - Stir fry strips – 5cm x 1cm (Eye of Round)

3.1.2   Microbial testing parameters

Each set of processed samples was sent for microbial testing after processing was completed and after a period in storage. The materials were tested for the following microbes and product parameters:

pH	Lactic Acid
Aw Test	Yeast/ Mold
Total Aerobic Standard Plate Count	Staph aureus
Coliforms	Bacillus
Listeria spp.	

3.1.3   Reconstitution Studies

The following reconstitution approaches were tested with ½ inch cubes:

1. With salt:
    a. Spray product sample with salt solution (25 gm kosher salt in 75 gm distilled water).
    b. Allow to dry.
    c. Take 2-3 cubes and:
        i. Soak in cold water (1.7 °C, 35 °F) for 5, 10, 15 and 20 minutes.
        ii. Boil in water (110 °C, 230 °F) for 5, 10, 15 and 20 minutes.
        iii. Fry in vegetable oil (113 °C, 235 °F) for 3, 5, 7, and 10 minutes.
2. No salt spray:
    a. Take 2-3 cubes and:
        i. Soak in cold water (1.7 °C, 35 °F) for 5, 10, 15 and 20 minutes.
        ii. Boil in water (110 °C, 230 °F) for 5, 10, 15 and 20 minutes.
        iii. Fry in vegetable oil (113 °C, 235 °F) for 3, 5, 7, and 10 minutes.

Sensory tests with the ½ inch cube processed product showed that soaking in cold water for 20 minutes, with no application of salt, provided the best results and this protocol was used for all other studies.

The reconstitution test for Stir-fry strips included an additional test for a refrigerated soak in cold water for six (6) hours. This yielded a texture and chewiness similar to fresh meat and provided a highly desirable sensory experience with the final product. Refrigeration and soaking for up to 6 hours is recommended for future tests for half-inch cubes and stir-fry strips.

3.1.4   Organoleptic testing protocol

TEF used the Meat Standards Australia (MSA) Assessment Form for Flavour Sensory evaluation provided by MLA for organoleptic assessment of the reconstituted samples. The following recipes were selected for the different sample cuts for each reconstitution and comparable product testing protocol.

½ Inch Sirloin Strip Cubed Beef - Soup Recipe

Ingredients

- 24 g beef
- 1 tablespoon vegetable oil
- 1/2 cup diced onion
- 1/2 cup diced celery
- 1/2 tsp. pepper
- 1/2 tsp salt
- 1 bouillon cube
- 1 tsp garlic powder
- 1 tsp dried basil
- 1 tablespoon fresh parsley
- 1 can (14.8 oz) canned tomatoes
- 1/4 red wine
- 1/2 cup water

Directions

1. Soak beef and measure.
2. Dice onions and celery. Sauté in oil for 10 minutes in a saucepan at 75 °C / 170 °F.
3. Add beef cubes and sauté for another 10 minutes.
4. Add spices, sauté for 1 minute, deglaze pan with red wine and water. Add tomatoes.
5. Simmer at 105 °C / 220 °F for 30 minutes.
6. Remove into container and test flavour, moisture, and water activity.
7. Chart for images, measure, and water activity.

80:20 Ground Beef – Hamburger Recipe

Ingredients

- 100 g beef (TEF) or 64 g (Freeze Dried) or 100 g (Fresh Beef)

Directions

1. Measure, soak, or boil beef and measure.
2. Form patties.
3. Fry patties.
4. Remove into container and test flavour, moisture, and water activity.
5. Chart for images, measure, and water activity.

90:10 Ground Beef – Bolognese Sauce Recipe

Ingredients

- Olive oil
- 1/4 cup chopped onion
- 1/4 cup chopped celery
- 8 oz (about 226.8 g) ground beef (fresh) or 4 oz (about 113.4 g) of ground beef (TEF) or 2.5 oz (about 70.87 g) of freeze dried
- 1 bouillon cube
- Spices (1/2 teaspoon dried basil, garlic & salt)
- 1 1/2 cup water
- 10 oz (about 283.5 g) of tomato paste
- 1 jar canned tomatoes (14.5 oz)
- 2 basil leaves
- 1 tsp fresh parsley
- 1/4 tsp salt and pepper

Directions

1. Dice onions and celery. Sauté in oil, in a saucepan, for 10 minutes at 7/ 170.
2. Add beef and brown for 5 minutes.
3. Add spices, sauté for 1 minute, add tomatoes and water.
4. Simmer at 105 °C/ 220 °F for 1 hour.
5. Remove into container and test flavour, moisture, and water activity. Taste with penne.

1x5 cm Eye of Round Stir-fry Strips – Stir-fry Recipe

Ingredients

- 2 tablespoons vegetable oil
- 1 tablespoon sesame oil
- 1/2-pound fresh beef or 1/2-pound TEF (rehydrated) beef, or 1/2 pound (rehydrated beef)
- 1 cup fresh broccoli florets
- 1 red bell pepper, cut into matchsticks
- 2 carrots, thinly sliced
- 1 green onion, chopped
- 1/2 teaspoon garlic powder
- 2 tablespoons soy sauce
- 2 tablespoons sesame seeds, toasted

Directions

1. Heat vegetable oil in a large wok or skillet over medium-high heat; cook and stir beef until browned, 3 to 4 minutes.
2. Move beef to the side of the wok and add broccoli, bell pepper, carrots, green onion, and garlic to the center of the wok. Cook and stir vegetables for 5 minutes.
3. Stir beef into vegetables and season with soy sauce and sesame seeds. Continue to cook and stir until vegetables are tender, about 2 more minutes.
4. Remove into container and test flavour, moisture, and water activity.
5. Serve hot with rice.

4. Results

4.1 Defining Processing Parameters

A range of predetermined Flavour Symmetry™ process conditions were tested to produce optimal conditions for rapid mass reduction and organoleptic profile retention for the identified sample materials to a water activity below 0.6.

Product Pictures

1-inch cubed meat
Starting material

a_w 0.9490 - 0.9849

Processed material

At 5 °C (41 °F)

Water Activity: 0.8919
At 24 °C (75 °F)
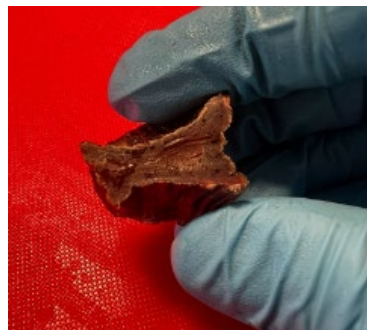
Water Activity: 0.7944

At 40 °C (105 °F)

Water Activity: 0.5811

1-inch-thick
Whole meat cuts
Starting material
a_w 0.9830 - 0.9692

Processed material

At 5 °C (41 °F)

Water Activity: 0.9436

At 24 °C (75 °F)

Water Activity: 0.8864

At 40 °C (105 °F)

Water Activity: 0.4122

Minced Meat 90:10
Starting Material

Processed material

At 24 °C (75 °F)

Water Activity: 0.2458

At 4 °C (40 °F), then at 15 °C (60 °F)
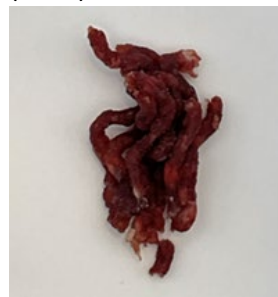
Water Activity: 0.1623

At 4 °C (40 °F), then at 24 °C (75 °F)

Water Activity: 0.2642

The TEF research team and the MLA project team discussed whether the project should focus on different types of meat cuts to see if they dehydrate differently or focus on different size cuts of

meats. The decision was made to focus on different sizes of meat cuts for this study. Future studies may evaluate whether different cuts of meat respond differently to the process conditions.
Microbial tests of the samples provided the following information:
No microbes detected for *Salmonella* spp., *Listeria monocytogenes* and *Escherichia coli* 0157:H7
CFU's/g for Aerobic plate count varied between <10 – 1400 in the samples tested.

1-inch Cubed Meat

Starting Material
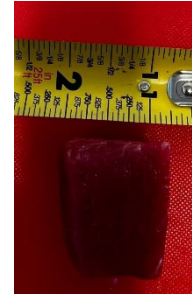
a_w 09118 -0.9415

Processed material

At 24 °C (75 °F)

Water Activity: 0.6363

At 4 °C (40 °F), then at 15 °C (60 °F)

Water Activity: 0.8440

At 4 °C (40 °F), then at 24 °C (75 °F)

Water Activity: 0.7512

0.50-inch cubed meat

Starting material

a_w 09118 -0.9415

Processed material

At 24 °C (75 °F)

Water Activity: 0.2631

At 4 °C (40 °F), then at 15 °C (60 °F)

Water Activity: 0.6246

At 4 °C (40 °F), then at 24 °C (75 °F)

Water Activity: 0.6813

0.25-inch Cubed Meat

Starting Material

a$_w$ 09118 -0.9415

Processed material

At 24 °C (75 °F)	At 4 °C (40 °F), then at 15 °C (60 °F)	At 4 °C (40 °F), then at 24 °C (75 °F)

Water Activity: 0.2192

Water Activity: 0.2379

Water Activity: 0.3682

5cm X 1cm Stir fry strips

Starting material

a$_w$ 0.9311 – 0.9511

Processed material

At 24 °C (75 °F)	At 4 °C (40 °F), then at 15 °C (60 °F)	At 4 °C (40 °F), then at 24 °C (75 °F)

Water Activity: 0.1321
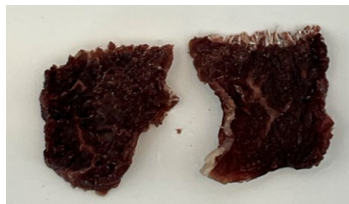
Water Activity: 0.3103

Water Activity: 0.4080

4.2 Processed Product Sample Results

This section describes the results of processing of the half-inch cube, ground meat (80:20 and 90:10) and stir-fry strips, samples using TEF FS technology.

4.2.1   Half-inch Sirloin Strip Cube Results

4.2.1.1   Dehydration Results

Sirloin strip steak was cut into half inch cubes and dehydrated in a FS system for 216 hours.

Table 1 (a). Change in Water Content and Water Activity of Half-inch Sirloin Strip Cubes.					
Product Sample	% Moisture		a_w		Wt. (g)	
	Starting	Ending	Starting	Ending	Starting	Ending
Half inch Cube	55.10	6.05	0.9401	0.5916	3140	1188

4.2.1.2   Microbial Test Results

Processed samples after dehydration were sent to Eurofins labs for Microbial analysis. The tests were run 6 days after samples were removed from the drying tunnel.

Table 1 (b).								
Microbial data for samples analysed five (5) days after processing.								
Lactic Acid Bacteria	Salmonella		Staphylococcus aureus		Aerobic Plate Count		Listeria	E. Coli
140 cuff/g	Not Detected		<10 cfu/g		1,300 cfu/g		Not Detected	Not Detected
Microbial data for samples analysed thirty-five (35) days after processing.								
Lactic Acid Bacteria	Salmonella	Staph. aureus	Yeast	Mold	Bacillus Ceres	Aerobic Plate Count	Listeria	E. Coli
80 cfu/g	Not Detected	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	300 cfu/g	Not Detected	Not Detected

4.2.1.3   Reconstitution Test Results

Half inch sirloin strip cubes were rehydrated using the conditions specified in Section 3.1.3. the following results were observed for the different conditions.

Table 1 (c). Half-inch Cube sprayed with salt solution and dried, then soaked in cold water (1.5 °C)					
	Time				
Measurement	0 Mins	5 mins	10 mins	15 mins	20 Mins
Length after (mm)	14.75	32.78	26.27	30.71	36.09
Width after (mm)	15.05	24.84	37.08	31.03	31.36
Height after (mm)	27.24	32.49	23.92	32.82	28.33
Water activity	.5916	0.8833	0.8488	0.8708	0.8808
Moisture %	6.05	11.49	14.80	18.55	16.56
Image before soaking					
Image after soaking					
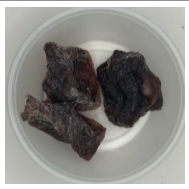
Table 1 (d). Half-inch Cube Sprayed with salt solution and dried, then boiled in 110 °C water					
	Time				
Measurement	0 Mins	5 mins	10 mins	15 mins	20 Mins
Length after	14.75	27.04	30.77	31.62	34.00
Width after	15.05	22.90	26.10	23.28	29.08
Height after	27.24	28.82	20.78	32.53	21.99
Water activity	.5916	0.9544	0.9091	0.9719	0.8683
Moisture %	6.05	5.59	9.89	12.50	17.05
Image before soaking					
Image -after soaking					
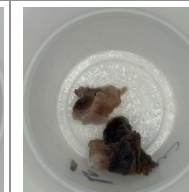
Table 1 (e). Half-inch Cube Sprayed soaked in 1.5 °C water – no salt treatment

Measurement	Time				
	0 Mins	5 mins	10 mins	15 mins	20 Mins
Length after	14.75	24.85	24.97	28.24	31.48
Width after	15.05	20.34	12.95	11.39	12.49
Height after	27.24	25.26	33.89	31.75	32.50
Water activity	.5916	0.7674	0.8099	0.8099	0.8002
Moisture %	6.05	15.04	20.17	15.35	18.24
Image before soaking					
Image -after soaking					

The results demonstrate that application of salt prior to soaking in water results in an initial shrinkage of the cubes and did not yield good rehydration.

Soaking the cubes in cold water for 20 minutes showed the best rehydration and subsequent sensory experience.

4.2.1.4   Organoleptic Tests

Table 1 (f). TEF dehydrated beef 1/2-inch cube in soup - no soak	
Cooked	20 Mins
Images	
Water activity	0.9590
Moisture	35.22
Taste	Slightly caramelized, deep beef flavour, slightly chewy

Tasting Notes (MSA Assessment Form)

Tenderness (out of 30 points)																													
NOT TENDER																											VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
									X																				

Juiciness (out of 10 points)									
NOT JUICY				VERY JUICY					
1	2	3	4	5	6	7	8	9	10
			X						

Flavour (out of 30 points																													
DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																			X										

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																						X							

Please circle a box:

☐ Unsatisfactory

X Good Everyday

☐ Better than everyday

☐ Gourmet

Table 1 (g). TEF dehydrated beef 1/2-inch cube in soup – with 20 min. soak	
Cooked	20 Mins
Images	
Water activity	0.9825
Moisture	28.62
Taste	Chewy, great beef flavour, slightly hard to cut

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																											VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
														X															

Juiciness (out of 10 points)									
NOT JUICY				VERY JUICY					
1	2	3	4	5	6	7	8	9	10
		X							

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																								X					

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30

Please circle a box:

☐ Unsatisfactory

☐ Good Everyday

X Better than everyday

☐ Gourmet

Table 1 (h). Freeze dried beef 1/2-inch cube in soup	
Raw	20 Mins
Images	
Water activity	0.9988
Moisture	51.47
Colorimeter	
Taste	Dry and chewy,

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																										VERY TENDER			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		X																											

Juiciness (out of 10 points)									
NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
X									

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
			X																										

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		X																											

Please circle a box:

X Unsatisfactory

☐ Good Everyday

☐   Better than everyday

☐ Gourmet

Table 1 (i). Fresh 1/2-inch beef cube in soup	
Raw	20 Mins
Image's	
Water activity	0.9995
Moisture	48.08
Taste	Dry and not much flavour, slightly tough

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																										VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
					X																								

Juiciness (out of 10 points)									
NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
X									

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
									X																				

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
								X																					

Please circle a box:

X Unsatisfactory

X Good Everyday

☐ Better than everyday

☐ Gourmet

The sensory studies demonstrated that for half inch cubes, TEF dehydrated meat soaked in cold water for 20 minutes and then cooked for 20 minutes in a soup base delivered a rich umami, beef flavour that was superior to the taste of fresh beef cubes and the freeze-dried cubes provided a very poor texture, flavour and taste experience. The TEF dehydrated beef cubes retained the fibrous

structure and mouth feel of beef. Additional cooking time may result in a more tender meat and could be considered for additional studies.

4.2.2   Ground Beef Results

4.2.2.1   Dehydration Results

Ground beef (90:10 and 80:20) were dehydrated in a FS 5 Series system for 41 hours.

Table 2(a) i. Change in Water Content and Water Activity of 90:10 Ground Beef.						
Product Sample	% Moisture		a_w		Wt. (g)	
	Starting	Ending	Starting	Ending	Starting	Ending
90:10 ground beef	48.67	0.96	0.9797	0.4767	1811	594

Table 2(b) i. Change in Water Content and Water Activity of 80:20 Ground Beef.						
Product Sample	% Moisture		a_w		Wt. (g)	
	Starting	Ending	Starting	Ending	Starting	Ending
80:20 ground beef	47.28	0.73	0.9849	0.4145	1854	800

4.2.2.2   Microbial Test Results

Processed samples after dehydration were sent to Eurofins labs for Microbial analysis.

Table 2 (a) ii.								
Microbial data for 90:10 Ground Beef samples analysed five (5) days after processing								
Lactic Acid Bacteria	Salmon-ella	Staph aureus	Yeast	Mold	Bacillus Ceres	Aerobic Plate Count	Listeria	E. Coli
<10 cfu/g	Not Detected	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	<100 cfu/g	Not Detected	Not Detected
Microbial data for 90:10 Ground Beef samples analysed sixty (60) days after processing								
Lactic Acid Bacteria	Salmon-ella	Staph aureus	Yeast	Mold	Bacillus Ceres	Aerobic Plate Count	Listeria	E. Coli
<10 cfu/g	Not Detected	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	Not Detected	Not Detected

Table 2 (b) ii.
Microbial data for 80:20 Ground Beef samples analysed five (5) days after processing

Lactic Acid Bacteria	Salmon-ella	Staph Aureus	Yeast	Mold	Bacillus Ceres	Aerobic Plate Count	Listeria	E. Coli
<10 cfu/g	Not Detected	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	10 cfu/g	Not Detected	Not Detected

Microbial data for 80:20 Ground Beef samples analysed thirty-five (35) days after processing

Lactic Acid Bacteria	Salmonella	Staph Aureus	Yeast	Mold	Bacillus Ceres	Aerobic Plate Count	Listeria	E. Coli
40 cfu/g	Not Detected	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	10 cfu/g	Not Detected	Not Detected

4.2.2.3 Reconstitution Test Results

Ground Beef samples were rehydrated using the conditions specified in Section 3.1.3.

4.2.2.4 Organoleptic Test Results

Table 2(a) iii. TEF processed 90:10 Ground Beef following Bolognese Recipe, with no soak

	Before	After soak or Boil	Amount Included	After Cooking
Images				
Weight	100g	n/a	100g	n/a
Water activity	0.5998	n/a	n/a	0.9877
Moisture	2.81%	n/a	n/a	52.92%
Tasting Notes	Good, rich flavour; meaty and very chewy. Very good overall, but a little tough and chewy.			

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																											VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	X																												

Juiciness (out of 10 points)

NOT JUICY				VERY JUICY					
1	2	3	4	5	6	7	8	9	10
				X					

Flavour (out of 30 points

DISLIKE EXTREMELY																	LIKE EXTREMELY							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
																			X					

Overall liking (out of 30 points)

DISLIKE EXTREMELY																	LIKE EXTREMELY							
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
								X																

Please circle a box:

X   Unsatisfactory

☐   Good Everyday

☐   Better than everyday

☐   Gourmet

Table 2 (a) iv. TEF processed 90:10 Ground Beef with 20-minute soak in 1.5 °C water and Bolognese recipe				
	Before	After soak or Boil	Amount Included	After Cooking
Images				
Weight	100g	158g	n/a	n/a
Water activity	0.5998	0.9876	n/a	0.9790
Moisture	2.81%	27.1%	n/a	60.24%
Tasting Notes	Great, rich meaty flavour, slightly caramelized, slight chewiness - kept going back for another bite - depth of flavour was above all three other tests.			

Tasting Notes

Tenderness (out of 30 points)

NOT TENDER																												VERY TENDER	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
														X															

Juiciness (out of 10 points)

NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
					X				

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																												X	

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																								X					

Please circle a box:

☐ Unsatisfactory

☐ Good Everyday

☐ Better than everyday

X Gourmet

Table 2 (a) v. Freeze dried 90:10 ground beef with a 20-minute soak in 1.5 °C water and then following Bolognese recipe				
	Before	After soak or Boil	Amount Included	After Cooking
Images				
Weight	64g	209g	205g	n/a
Water activity	0.1709	0.9882	n/a	0.9885
Moisture	0.92%	44.64%	n/a	67.78%
Tasting Notes	Not a pleasant smell, spongy, dry and crumbly mouthfeel, no meat flavour.			

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																												VERY TENDER	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	X																												

Juiciness (out of 10 points)									
NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
	X								

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
				X																									

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		X																											

Please circle a box:

X Unsatisfactory

☐ Good Everyday

☐ Better than everyday

☐ Gourmet

Table 2 (a) vi. Fresh 90:10 ground beef following Bolognese sauce recipe				
	Before	After soak or Boil	Size	After Cooking
Images				
Weight	150g	n/a	150g	n/a
Water activity	0.9818	n/a	n/a	0.9812
Moisture	65.87%	n/a	n/a	63.81%
Tasting Notes	Traditional Bolognese sauce taste. Slight beef flavour.			

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																											VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
														X															

Juiciness (out of 10 points)									
NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
				X					

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																	X												

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																		X											

Please circle a box:

☐ Unsatisfactory   ☐ Better than everyday

X Good Everyday   ☐ Gourmet

Table 2 (b) iii. TEF processed 80:20 Ground Beef with 20-minute soak in 1.5 °C water following Hamburger recipe

	Before	After soak or Boil	Patty Size	After Cooking
Weight	100g	131g	100g	78g
Water activity	0.5976	0.9869	n/a	0.9555
Moisture	1.92%	18.25%	n/a	11.69%
Tasting Notes	The hamburger has a deep, rich and meaty flavour. Slight chewy and crumbly. Crispy like the edges of a smash burger. Further studies will be undertaken with a longer soak once more product is available for testing.			
Images				

Tasting Notes (MSA Assessment Form)

Tenderness (out of 30 points)

NOT TENDER ... VERY TENDER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
										X																			

Juiciness (out of 10 points)

NOT JUICY   VERY JUICY

1	2	3	4	5	6	7	8	9	10
	X								

Flavour (out of 30 points

DISLIKE EXTREMELY ... LIKE EXTREMELY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																											X		

Overall liking (out of 30 points)

DISLIKE EXTREMELY ... LIKE EXTREMELY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																			X										

Please circle a box:
- ☐ Unsatisfactory
- ☐ Good Everyday
- X Better than everyday
- ☐ Gourmet

Table 2 (b) iv. Freeze dried ground beef, 20-minute soak in 1.5 °C water following Hamburger recipe

	Before	After soak or Boil	Patty Size	After Cooking
Images				
Weight	64g	205g	100g	66g
Water activity	0.1709	0.9882	n/a	0.9843
Moisture	0.92%	44.64%	n/a	28.49%
Tasting Notes	Spongy texture, dry and crumbly. No flavour. Appearance like a traditional beef patty.			

Tasting Notes

Tenderness (out of 30 points)

NOT TENDER																													VERY TENDER
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
	X																												

Juiciness (out of 10 points)

NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
	X								

Flavour (out of 30 points

DISLIKE EXTREMELY																													LIKE EXTREMELY
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
					X																								

Overall liking (out of 30 points)

DISLIKE EXTREMELY																													LIKE EXTREMELY
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
				X																									

Please circle a box:

X   Unsatisfactory

☐   Good Everyday

☐   Better than Everyday

☐   Gourmet

Table 2 (b) v. Fresh 80:20 Ground Beef with 20-minute soak in 1.5 °C water following Hamburger recipe			
	Before	Patty Size	After Cooking
Images			
Weight	100g	100g	69g
Water activity	0.9837	n/a	0.9755
Moisture	56.5%	n/a	37.93%
Tasting Notes	Traditional hamburger		

Tasting Notes

Tenderness (out of 30 points)

NOT TENDER   VERY TENDER

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
									X																				

Juiciness (out of 10 points)

NOT JUICY   VERY JUICY

1	2	3	4	5	6	7	8	9	10
			X						

Flavour (out of 30 points

DISLIKE EXTREMELY   LIKE EXTREMELY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
													X																

Overall liking (out of 30 points)

DISLIKE EXTREMELY   LIKE EXTREMELY

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
											X																		

Please circle a box:

☐   Unsatisfactory

X   Good Everyday

☐   Better than everyday

☐   Gourmet

The sensory studies demonstrated that TEF processed ground beef resulted in a product with a more intense meaty flavour over fresh ground beef, while freeze dried ground beef resulted in an undesirable end product. Additional tests with a longer soak time are recommended for future studies with ground beef.

4.2.3 Stir-fry strips

4.2.3.1 Dehydration Results

5 cm x ½ cm stir-fry strips were dehydrated in a FS 5 Series system for 47.5 hours.

Table 3 (a) . Change in Water Content and Water Activity of Stir-fry Strips						
Product Sample	% Moisture		a_w		Wt. (g)	
	Starting	Ending	Starting	Ending	Starting	Ending
90:10 ground beef	68.14	2.05	0.9831	0.5377	1437	575

4.2.3.2 Microbial Test Results

Processed samples after dehydration were sent to Eurofins labs for Microbial analysis.

Table 3 (b). Microbial data for samples analysed five (5) days after processing.								
Lactic Acid Bacteria	Salmonella	Staph Aureus	Yeast	Mold	Bacillus Ceres	Aerobic Plate Count	Listeria	E. Coli
<10 cfu/g	Not Detected	<10 cfu/g	<10 cfu/g	<10 cfu/g	<10 cfu/g	120 cfu/g	Not Detected	Not Detected

4.2.3.3 Reconstitution Results

Stir-fry Strips were rehydrated using the conditions specified in Section 3.1.3. the following results were observed for the different conditions. An additional rehydration test was conducted by soaking the stir-fry strips in cold water (1.7 °C, 35°F) under refrigeration for 6 hours. These samples provided the best sensory results.

4.2.3.4 Organoleptic Test Results

Table 3 (c). TEF Processed Stir-fry beef strips with a 20-minute soak in 1.5 °C water and then following stir-fry recipe			
	Before	After soak or Boil	After Cooking
Images			
Water activity	0.6897	0.9270	n/a
Moisture	2.80%	21.39%	n/a
Tasting Notes	Outstanding rich beef flavour, texture was very chewy. (Recipe had no water in it, once soak of 20 minutes was complete rehydration stopped.)		

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																											VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
		X																											

Juiciness (out of 10 points)									
NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
	X								

Flavour (out of 30 points																													
DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																									X				

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
							X																						

Please circle a box:

X   Unsatisfactory (Due to chewiness)

☐   Good Everyday

☐   Better than everyday

☐   Gourmet

Table 3 (d). TEF Processed Stir-fry beef strips with a 6-hour soak in 1.5 °C water, under refrigeration, and then following stir-fry recipe.			
	Before	After soak or Boil	After Cooking
Images			
Water activity	0.6897	0.9656	n/a
Moisture	2.80%	46.22%	n/a
Tasting Notes	Outstanding rich deep beef flavour like aged meat. Texture was like fresh meat with a slight chew.		

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																											VERY TENDER		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																									X				

Juiciness (out of 10 points)									
NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
								X	

Flavour (out of 30 points																													
DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																											X		

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
																										X			

Please circle a box:

☐ Unsatisfactory   ☐ Better than everyday

☐ Good Everyday   ☐ X Gourmet

Table 3 (e). Freeze Dried Stir-fry beef strips following packet instructions and following stir-fry recipe			
	Before	After soak	After Cooking
Images		Image not collected	
Water activity	0.1049	0.9923	n/a
Moisture	2.00%	50.34%	n/a
Tasting Notes	Tenderness was along the lines of fresh meat in chewiness. It had a slight off smell and mild beef flavour. Could tell it was meat but not that it was beef.		

Tasting Notes

Tenderness (out of 30 points)

NOT TENDER																												VERY TENDER	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
									X																				

Juiciness (out of 10 points)

NOT JUICY					VERY JUICY				
1	2	3	4	5	6	7	8	9	10
				X					

Flavour (out of 30 points

DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
						X																							

Overall liking (out of 30 points)

DISLIKE EXTREMELY																											LIKE EXTREMELY		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
								X																					

Please circle a box:

☐ Unsatisfactory   ☐ Better than everyday

X Good Everyday   ☐ Gourmet

Table 3 (f). Fresh Stir-fry beef strips following stir-fry recipe			
	Before	After soak	After Cooking
Images		Image not collected	
Water activity	0.9747	.9794	n/a
Moisture	58.86%	49.00%	n/a
Tasting Notes	Traditional stir-fry - slight chewiness that one expects in stir fry. Traditional beef flavour.		

Tasting Notes

Tenderness (out of 30 points)																													
NOT TENDER																										VERY TENDER			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
									X																				

Juiciness (out of 10 points)									
NOT JUICY				VERY JUICY					
1	2	3	4	5	6	7	8	9	10
		X							

Flavour (out of 30 points																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
								X																					

Overall liking (out of 30 points)																													
DISLIKE EXTREMELY																										LIKE EXTREMELY			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
								X																					

Please circle a box:

☐ Unsatisfactory

X Good Everyday

☐ Better than everyday

☐ Gourmet

The sensory studies demonstrated that TEF processed stir-fry soaked for six hours in a refrigerated environment resulted in a product with an ooutstanding rich deep beef flavour like aged meat with a texture was like fresh meat with a slight chew. The team indicated that they kept going back for seconds. Sensory studies with TEF-processed stir-fry soaked for twenty minutes in cold water resulted in a chewy product that was undesirable.

5. Conclusion

5.1 Key findings

5.1.1   Dehydration

Based on the studies to date, TEF has demonstrated that FS has potential to create small sized, shelf-stable cuts of meat. Steak cubes up to 0.5 inches in diameter, 1x5 cm stir fry strips and minced beef have excellent drying characteristics under FS process conditions. Microbial testing of the freshly processed materials demonstrates no detectable pathogenic bacteria and an acceptable level of aerobic mesophilic bacteria, indicating that the processing conditions are safe. Additional storage stability studies showed that the product was shelf stable at room temperature for up to 65 days post processing.

5.1.2   Reconstitution

Reconstitution studies were undertaken with half-inch cubes of sirloin steak with different rehydration methods including: soaking for different periods of time in raw water, boiling, and frying; with and without the application of a salt spray. Soaking in cold water for 20 minutes yielded the best results and was the preferred method used for reconstituting processed ground beef and stir-fry strips. Sensory testing has suggested that soaking for an additional period of time may yield a more tender product and may be considered for future studies.

5.1.3   Sensory Evaluation

Organoleptic studies with half inch cubes of sirloin steak provided a more intense meat flavour product in comparison with fresh meat in a soup application. 80:20 ground beef in a hamburger application yielded an elevated beef flavour than a fresh meat patty, although its texture was crumbly and crisp and did not hold together as well as a fresh beef patty. 90:10 ground beef in a Bolognese sauce application provided a more intensely flavourful, gourmet product compared to its fresh beef counterpart. Stir-fry eye of round beef strips in a stir fry recipe provided an intensely flavourful, gourmet product with a rich aged beef taste and a texture of fresh meat with a longer soak of six hours in cold water under refrigeration.

Freeze dried meat was also prepared for each application as a comparable. All applications of freeze-dried beef, except for stir-fry strips, were found to be undesirable with a lack of flavour, undesirable texture and in some cases an off-putting odour during preparation.

5.1.4   Ambient supply chain potential for shelf stable red meat products produced Reconstitution through TEF FS technology

Microbial tests affirmed and safety of the process and the product and longer-term stability studies are in progress. Additional storage stability studies showed that the product was shelf stable at room temperature for up to 65 days post processing.

5.2 Benefits to industry

The study clearly demonstrated the potential to apply TEF FS Technology to make a new organoleptically superior, shelf stable, red meat product that can be used to reach markets that are currently limited in the use of raw red meat. Initially, a TEF processed product would allow remote communities, campers, disaster relief and other situations that may lack refrigeration to have access to raw red meat for various food applications. The technology is easy to implement, and initial economics of the technology appear profitable.

- TEF FS technology can be used to dehydrate half-inch cubes, ground beef and stir-fry strips to a water activity of less than 0.6, to form a pliable, dry product that reconstitutes by soaking in cold water and retains the organoleptic properties of the original raw meat in different cooking applications like soups, Bolognese sauce and stir fry.
- Ground beef in a Bolognese sauce and stir fry strip applications provided a gourmet product with a rich and meaty flavour and far improved over freeze dried meat products.
- The dehydrated products were shelf stable under ambient storage conditions for up to 65 days. The study was terminated at this period. Based on the results to date, longer storage times are likely to be attainable if the tests are carried on for a longer period of time.
- Larger cuts of meat took a longer time to dry and the ideal cuts for this application are ground beef (80:20 and 90:10) and stir-fry strips.
- TEF FS technology can be used to dehydrate ground beef and stir-fry strips to a water activity of less than 0.25 to form a crumbly powdered product that would be ideal for soup mixes and flavourings. This was not pursued further as the focus of the project was to make dehydrated products that retained the mouthfeel and texture of fresh red meat.
- A dehydrated red meat product produced using the TEF FS System could create a valuable new, shelf-stable, product that is superior in taste, flavour and texture to fresh meat and that may be stored at room temperature and be transported through an ambient supply chain.

6. Future research and recommendations

The preliminary work done under this project shows promise for the development of high quality, flavourful, dehydrated shelf stable red meat products, with good texture and mouthfeel, that can be stored and transported at ambient temperature. This could open a significant new market opportunity and supply channel for Australian meat and livestock producers.

A larger scale, longer term study to better define dehydration parameters would be useful to define processing efficiencies and that would help define manufacturing costs of the TEF FS technology. Collaboration with large scale processors would also be useful to define product handling parameters and develop a system for large scale industrial implementation.

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