final report

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Evaluation of the potential for sous vide processing in the red meat industry

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Abstract

This project is a scoping level study that covers a range of issues associated with sous-vide processing. The objective of the work is to review existing technologies for the processing of sous-vide red meat products, identify potential markets and provide a report that identifies where there is potential for the use of sous-vide processing to develop products that will add value to products for the red meat industry.

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1. Glossary

Clostridium botulinum: A rod-shaped microorganism which produces spores which remain dormant until they are placed in a low-oxygen environment. Under ideal conditions, C. botulinum produces botulin, a substance so toxic that less than 1 microgram can kill a healthy person by paralysing all the muscles in the body, including the heart. [3]

Combi oven: A professional cooking appliance commonly used in commercial kitchens. It combines the functions of a convection oven and a steam cooker and can thus produce dry heat, moist heat or a combination of the two at various temperatures.

Critical Control Point: A point, step or procedure at which controls can be applied and a food safety hazard can be prevented, eliminated or reduced to acceptable levels. Critical control points are identified in a Hazard Analysis Critical Control Point (HACCP) plan which is a systematic preventive approach to food safety that addresses physical, chemical, and biological hazards as a means of prevention rather than finished product inspection.

D-value: In microbiology the D-value or decimal reduction time is the time required at a specified temperature to kill 90% of the target organisms.

Hurdle: In food microbiology the terms ‘hurdle’ refers to preservation factors or techniques utilised to prevent the propagation of pathogens.

Listeria monocytogenes: Aerobic non-spore forming bacterium commonly found in agricultural products and foods. This pathogen is of particular concern in chilled foods because of its ability to propagate at temperatures close to freezing and at a wide range of pH and water activity (A_w) values.

Malliard reaction: A chemical reaction between an amino acid and a reducing sugar, usually requiring heat forming a complex mixture of poorly characterized molecules responsible for a range of odours and flavours. The Malliard reaction is responsible for colours and flavours such as the browning of meat and the crust of cakes and breads.

Myofibrils: Cylindrical bundles of filaments found within individual muscle meat cells. Myofibrils run longitudinally along the muscle cell attaching to the cell surface membrane at each end.

Pasteurisation: Pasteurisation is a process of heating food to a specific temperature for a definite length of time, and then cooling it immediately. Its purpose in food processing is to reduce the number of vegetative pathogens to a safe level. However, for sous vide processing this is not always the case. For the purposes of this report pasteurisation simply refers to a cooking process with specific time and temperature set points.

Proteolytic enzymes: A group of enzymes that break the long chainlike molecules of proteins into shorter fragments known as peptides and eventually into their components, amino acids.

1.1 Abbreviations

ACMSF – UK Advisory Committee on Microbiological Safety of Food

AIFST – Australian Institute of Food Science and Technology

AQIS – Australian Quarantine and Inspection Service

CCFRA – Campden and Chorleywood Food Research Association

CCP – Critical Control Point

CFSAN – US Center for Food Safety and Applied Nutrition

FDA – US Food and Drug Administration

FSANZ – Food Standards Australia New Zealand

HACCP – Hazard Analysis and Critical Control Points

HPP – High Pressure Processing

LT-LT – Low Temperature - Long Time

SVAC – Sous Vide Advisory Committee

2. Executive Summary

2.1 Project Scope

This project is a scoping level study that covers a range of issues associated with sous-vide processing. The objective of the work is to review existing technologies for the processing of sous-vide red meat products, identify potential markets and provide a report that identifies where there is potential for the use of sous-vide processing to develop products that will add value to products for the red meat industry.

2.2 Project Outcomes

This project has involved a desktop study that addresses a number of issues and aspects of the sous-vide process, including:

- A definition of the process and its application for the purposes of this project;
- Identification of suppliers of equipment and the typical installation and operating parameters for the equipment;
- A review of the food safety and other risks associated with the process;
- Identification of potential risk management strategies to mitigate the safety risks associated with sous vide processing;
- Identification of possible product developments that would be suited to the use of sous-vide processing processes;
- Potential added value for products using the process (the increase in value after the inclusion of additional costs); and
- Identification and comparison of competing and/or complementary processes and technologies.

2.3 Key Reporting Points

- The sous vide process essentially consists of four stages which are listed as follows:
  1. Vacuum packaging;
  2. Pasteurisation;
  3. Chilling; and
  4. Finishing for service.
- In terms of the pasteurisation process, low temperature – long time cooking conditions are recommended in order to maximise the sensory qualities of the finished product and minimise the cooking losses incurred. For lower grade cuts of red meat that typically contain higher amounts of connective tissue, cooking between 50°C to 65°C is recommended for as long as 24 hours to 48 hours.
- Critical to the pasteurisation process is maintaining a constant cooking temperature, ideally to within ±1°C variance from the temperature setpoint. Chilling the product as quickly as possible after pasteurisation is also essential unless the product is to be consumed immediately. After the pasteurisation process, sous vide products must be rapidly chilled and stored between 0°C and 3°C.

- Section 6 of this report provides an estimate of the theoretical capital costs of setting up commercial sous vide processing operations and the associated annual operating costs. In this report we have considered theoretical processing lines that have provided the following estimated sous vide processing costs: [1]
  - 900 kg/day throughput using combi ovens – $2.07 per kg ($1.04 per pack)
  - 900 kg/day throughput using cook-chill tanks – $1.44 per kg ($0.72 per pack)
  - 2700 kg/day throughput using cook and chill tanks – $0.98 per kg ($0.49 per pack)

  The pack size used in this cost estimate was 500g [2] meat products vacuum sealed in 200 mm x 250 mm pouches. It should be also noted that the labour costs constituted between 65% and 67% of the total processing costs.
- Cooking in the pack retains moisture in the vacuum pack leading to a reduced yield loss at retail and food preparation stages of the product as well as an improved product to the consumer.
- In this milestone report we have used a 500g meat product for sizing and pricing. At this product size product may be sold in the process packaging removing the need for further retail packaging.
- Given the reputed enhanced eating qualities of sous vide product it would be reasonable to look for a higher price at retail level recovering the costs of processing.
- Achieving the equivalent time-temperature pasteurisation process as outlined in the relevant regulations may be an issue if the optimum temperature range of 50°C to 65°C is utilised for the pasteurisation process. However, there is potential for the application of additional hurdles that manipulate properties such as the acidity and salinity of the product in order to provide additional food safety confidence and extended the allowable shelf life.
- For the retail market, the post-purchase temperature abuse and adequacy of finishing procedures to kill surface bacteria will be not be able to be controlled. These risks will need to be managed through education and possibly scaling back the shelf life of the product to allow for a worst case scenario.
- There is an existing market for sous vide meat products in Australia, primarily in the food service and commercial catering industries. Off the shelf sous vide meat products are scarcely available at a retail level.
- The most significant marketable attribute of sous vide processing is the increased tenderness and sensory qualities as compared to conventional cooking methods particularly for the tougher lower grade cuts of beef. Considering this and the relative pricing between the various cuts of beef there is potential for sous vide processing in the low end cuts of beef and in the “Smartbuy Economy” and “Market Value” brand products.
- In general the opportunities for producing sous vide lamb products are very limited.
- There is always the potential that developing sous vide beef products could cannibalise the existing fresh meat market. For the opportunities identified in this study, this would generally affect the premium and mid-range cuts of beef.

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[1] These costs are only estimates based on specific parameters and may not be relied on. Processors considering sous vide processing will need to make their own evaluation of costs using their own inputs and parameters.

[2] 500 g pack size based on a two person serve. Larger pack sizes will reduce the $/kg costs.

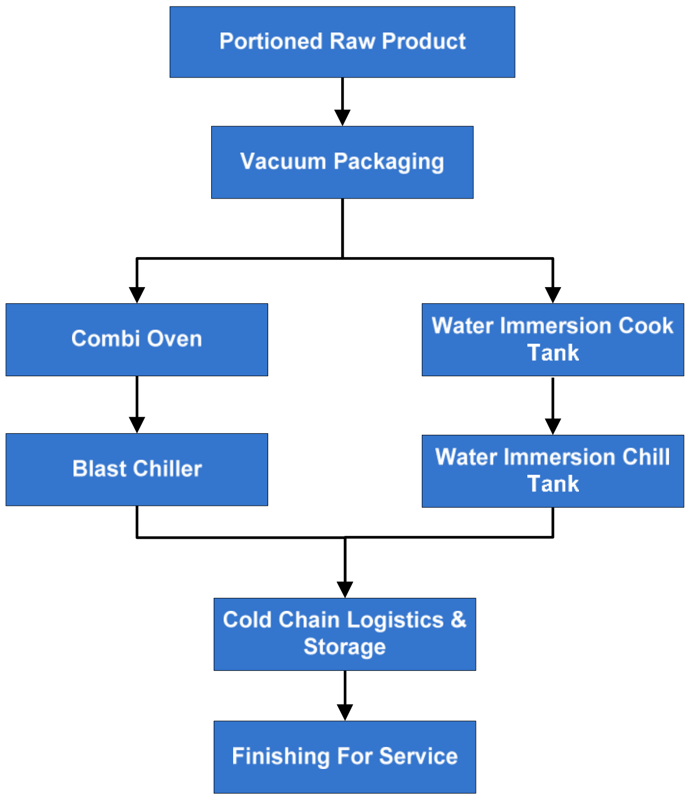
3. Introduction/Context of the Report

For this report we have provided a definition of the sous vide process and its application in terms of processing red meat products. The outcome of the project will assist in identifying the potential of sous vide processing opportunities to add value to red meat products.

Essentially the sous vide process consists of vacuum packaging, pasteurisation, rapid chilling, cold storage, and finally, finishing for service. Figure 1 below shows a flowchart of a typical sous vide process. In this report we have considered two methodologies for the cooking and rapid chilling stages. These are firstly the use of combi ovens and blast chillers, and secondly the use of cook and chill water immersion tanks.

A detailed discussion of the process including an analysis of cooking parameters is provided in Section 4. Section 5 provides details of the capital costs and operating parameters associated with sous vide processing equipment. In addition, capital and operating costs have been estimated with respect to setting up manufacturing operations of varying throughput capacities in Section 6. Section 7 and Section 8 discuss the food safety issues associated with the process and potential product developments respectively.

Figure 1: Flowchart of the Sous Vide Process



4. Definition of the Sous-Vide Process

A widely accepted definition of the sous vide process is that which was put forward by the Sous Vide Advisory Committee (SVAC)[1]; "*sous vide is an interrupted catering system in which raw or par cooked food is vacuum sealed in a laminated plastic pouch or container, heat treated by controlled cooking and then reheated for service after a period of chilled storage*". For red meat products the cooking process is typically based on a Low Temperature - Long Time (LT-LT) relationship. [2,3]

Essentially there are four stages of the process which are as follows:

1. Vacuum packaging;
2. Pasteurisation;
3. Chilling; and
4. Finishing for service.

The key benefits of sous vide cooking when compared to conventional cooking methods are greater sensory quality and nutritional benefits and reduced yield losses of the finished product. There are also operational benefits with respect more efficient use of labour in a commercial kitchen environment. [2,4]

The four stages of the process will be discussed in the following sections of this report with respect to the production of sous vide red meat products.

4.1 Vacuum Packaging

4.1.1 Purpose and nutritional benefits

Vacuum packing raw or par cooked product in a hermetically sealed plastic pouch prior to cooking is a defining element of the sous vide process. This minimises lipid oxidation and preserves both the sensory qualities and colour of the product. [4] Vacuum sealing also prevents evaporative losses and leaching of moisture and volatile compounds during cooking which are typical of conventional cooking methods. As a result, flavours tend to be amplified and less seasoning is required, lowering the overall sodium content of sous vide foods. Studies have shown that compared with conventional cook – chill methods, sous vide meat dishes exhibited better post processing retention of A, B, C, D and E vitamins. However, these benefits gradually diminish after consequent chilled storage and reheating. [3]

[1] The SVAC was established out of the need to develop a code of practice for sous vide cooking. Its members included representatives of sous vide practitioners, equipment manufacturers and research establishments. A code of practice for sous vide catering systems was published by the SVAC in 1991.

[2] Vaudagna, S. et al. (2002). Sous vide cooked beef muscles: effects of low temperature–long time (LT–LT) treatments on their quality characteristics and storage stability. International *Journal of Food Science and Technology*, 37, 425 – 441.

[3] Creed, P. (2000). Sous Vide - An Overview of the Process. Teagasc Publications, Ready Meals Conference, 2000. <http://www.teagasc.ie/publications/readymeals2000/paper03.asp> Accessed 22/02/11.

[4] Tiampo. J. (2006). Seal Appeal: The Nutrition, Food Safety, and Operational Benefits of Sous Vide. <http://www.techne-calibration.com/adminimages/Sous_Vide_Information(1).pdf> Accessed 21/02/11.

4.1.2 Operational benefits

Often sous vide meat products are vacuum packed with marinades or a mixture of herbs and spices. The operational benefit of sous vide in these cases is that the holding time for marinating is eliminated as flavour infusing occurs during the pasteurisation process. [1]

Another significant benefit of sous vide cooking when compared to conventional cooking methods is that the cooking losses are captured in the bag. These can then be retained and marketed as an addition to the finished product that is sold to the consumer. This principle has been employed by Byropin Meats who produce sous vide roast joints. The cooking losses or 'jus' are sold as part of the finished product as a key constituent in preparing an accompanying gravy or sauce for the meat. [2] In conventional cooking processes involving cooking prior to bagging and chilling, these cooking losses simply evaporate in the oven or leach into the cooking medium and thus cannot be utilised.

4.1.3 Safety Concerns

A widely documented benefit of sous vide processing is that the low oxygen partial pressure present in vacuum sealed pouches prevents the growth of aerobic bacteria during the pasteurisation and chilled storage processes. However, it is these conditions along with the relatively low cooking temperature that provide an ideal environment for the propagation of anaerobic bacteria. Of these pathogens, Clostridium botulinum has been the primary focus in many scientific studies due to its toxicity and heat resistant properties. [3,4] The safety issues and risk management procedures associated with sous vide processing are discussed in Section 7 of this report. However, it is important to note at this stage that the food preparation and vacuum packing process will be a Critical Control Point (CCP) in commercial scale sous vide operations, and quite possibly the most important step in ensuring product quality and safety. It is recommended that a chilled and segregated hygienic product packing (pre-cooking) area will be required in a large scale operation. The working environment would be between 3°C and 10°C with a preference for lower temperatures. [4]

4.2 Pasteurisation

In commercial kitchens and large scale operations steam/forced convection combination ovens and water immersion batch cook tanks are the most common technologies available in the market. These will be discussed in detail in Section 5 of this report.

4.2.1 Cooking time and temperature set-points

For red meat products the pasteurisation process is typically based on a LT-LT relationship. This is essential in ensuring a uniform level of doneness throughout the product even with very large joints of meat. It has also been shown that LT-LT cooking tenderises cheaper cuts of meat with high connective

[1] Langford. S. (2009). Under Pressure. *Foodservice and Hospitality*. Vol 41. No. 12. February 2009.

[2] Byropin Meats Pty Ltd. (2005). Some information regarding our "Sous Vide" meat. <http://www.bryopin.com.au/Publications/Microsoft%20Word%20-%20Some%20information%20sous%20vide.pdf> Accessed 17/02/11.

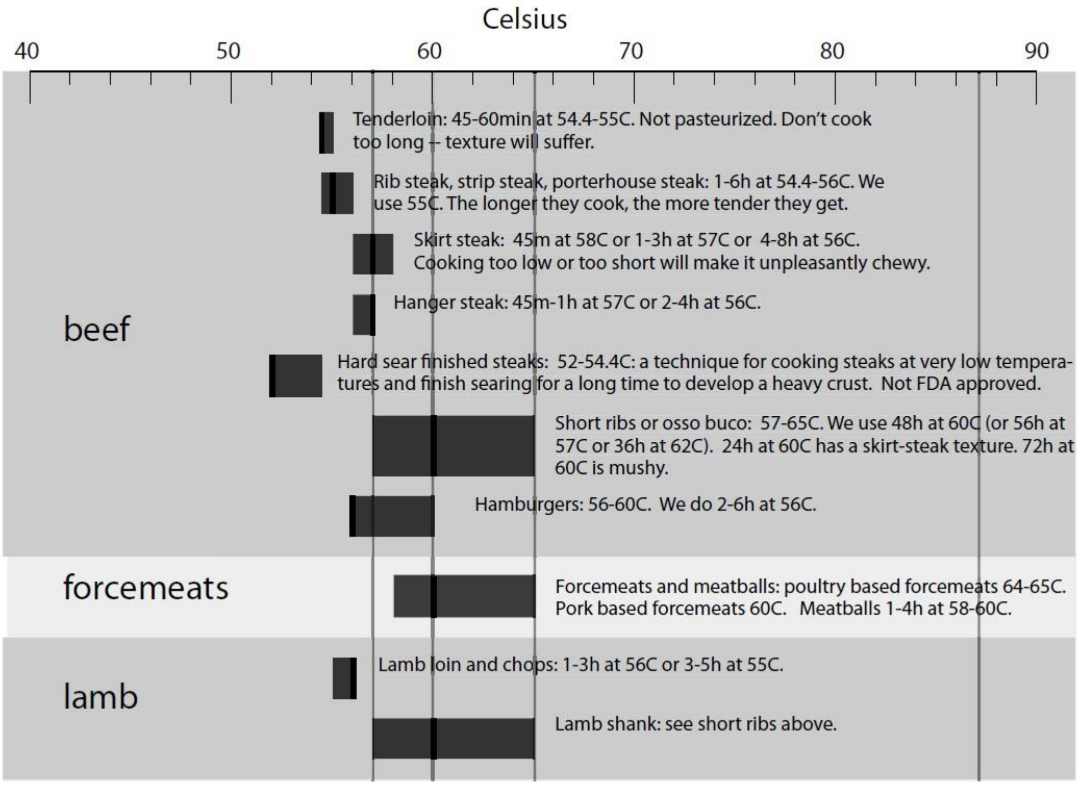
[3] Vaudagna, S. et al. (2002). Sous vide cooked beef muscles: effects of low temperature–long time (LT–LT) treatments on their quality characteristics and storage stability. *International Journal of Food Science and Technology*, 37, 425 – 441.

[4] Tiampo. J. (2006). Seal Appeal: The Nutrition, Food Safety, and Operational Benefits of Sous Vide. <http://www.techne-calibration.com/adminimages/Sous_Vide_Information(1).pdf> Accessed 20/02/11.

tissue content. [1] These effects have been shown to occur within approximately 12 to 24 hours with tenderness increasing only slightly when cooked for 50 to 100 hours. Bouton and Harris (1981) found that tough cuts of beef were most tender when cooked between 55°C and 60°C. The tenderising of the meat is the result of the hydrolysis of collagen forming gelatine and the weakening of myofibrillar tensile strength by proteolytic enzymes at low temperatures. Furthermore, the sarcoplasmic protein enzyme collagenase remains active below 60°C and can significantly tenderise meat if held for over 6 hours. [2]

The findings in the literature appear to correlate with the recommendation of chefs who utilise the sous vide method. Figure 2 illustrates the time temperature settings for various products suggested by the French Culinary Institute. For red meats 50°C to 65°C appears to be the ideal temperature range for sous vide cooking.

Figure 2: Suggested Time-Temperature Settings for Sous Vide Red Meat Products [3]



Vaudanga et al. (2002) examined the effects of different LT-LT treatments within the optimum temperature band of 50°C to 65°C on the cooking losses and tenderness of sous vide cooked beef muscles. Various tests were conducted. The results showed that tenderness increased as well as

[1] Rodgers. S. (2008). Technological Innovation Supporting Different Food Production Philosophies in the Food Service Sectors. *International Journal of Contemporary Hospitality Management*, 20, 19 – 34.

[2] Baldwin, D. (2008). A Practical Guide to Sous Vide Cooking. <http://www.douglasbaldwin.com/sous-vide.html> Accessed 01/03/11.

[3] French Culinary Institute's Technical Blog. Low Temperature Charts. <http://www.cookingissues.com/uploads/Low_Temp_Charts.pdf> Accessed 02/03/11.

cooking weight losses as the temperature was raised from 50°C to 65°C. Processing times did not have a significant impact on product quality. However, the study did not consider extended processing times of over 6 hours.[1] The temperature – tenderness relationship proposed by Vaudanga et al. (2002) has also been reiterated by Baldwin (2008) who suggested that in general, the tenderness of meat increases from 50°C to 65°C cooking temperature and then decreases up to 80°C.

The ideal time-temperature set-points for the pasteurisation process will largely depend on the technical aspects of the recipe. As such a chef experienced in sous vide cooking and possibly an appropriately qualified food scientist should be consulted in the early stages of product development. In addition, relevant regulations will restrict the operating parameters of the pasteurisation process. These will be discussed in Section 7.

4.2.2 Nutritional benefits associated with LT-LT cooking

In addition to the benefits associated with sensory qualities, LT-LT sous vide cooking of red meat products has also been shown to have nutritional benefits. The low temperature nature of the process means that little additional fat is required to prevent the adhesion of proteins to the cooking surface. Any added fats or oils would be solely for flavour enhancement. [2] These nutritional benefits, along with those discussed in Section 4.1, could potentially be used to market sous vide products as a healthier alternative to conventionally prepared meat products. There may be potential for the sous vide meat products to gain heart tick approval and be incorporated into Weight Watchers style meals. The identification of potential product developments and markets will be discussed in detail in the next milestone report.

4.2.3 Yield losses associated with LT-LT cooking

Studies have shown that yield losses for red meats are dependant the cooking temperature but are not significantly affected by cooking time. Vaudanga et al. (2002) examined the effects of different LT-LT sous vide treatments on the cooking losses of beef muscles. It was found that cooking losses increased significantly as the cooking temperature was raised from 50°C to 65°C. However, cooking time had no significant effect on the yield losses incurred. [1]

Similarly, Byropin Meats' publication on sous vide processing suggests that yield losses are dependent on the level of doneness and hence the cooking temperature. The following figures for yield losses have been proposed by Baldwin (2008) and Byropin Meats (2005): [3,4]

- Rare meat (51.5°C corresponding temperature) – 15% yield loss;
- Medium rare meat (54.5°C corresponding temperature) – 20% yield loss;
- Medium meat (60°C corresponding temperature) – 25% yield loss;

[1] Vaudagna, S. et al. (2002). Sous vide cooked beef muscles: effects of low temperature–long time (LT–LT) treatments on their quality characteristics and storage stability. *International Journal of Food Science and Technology*, 37, 425 – 441.

[2] Tiampo. J. (2006). Seal Appeal: The Nutrition, Food Safety, and Operational Benefits of Sous Vide. <http://www.techne-calibration.com/adminimages/Sous_Vide_Information(1).pdf> Accessed 20/02/11.

[3] Baldwin, D. (2008). A Practical Guide to Sous Vide Cooking. <http://www.douglasbaldwin.com/sous-vide.html> Accessed 01/03/11.

[4] Byropin Meats Pty Ltd. (2005). Some information regarding our "Sous Vide" meat. <http://www.bryopin.com.au/Publications/Microsoft%20Word%20-%20Some%20information%20sous%20vide.pdf> Accessed 17/02/11.

- Well done meat – 30% yield loss;

Offer et al. (1984) stated that water losses during meat cooking occur in two distinct phases, the first phase occurs at temperatures from 45°C to 60°C where the shrinkage of meat is mainly transverse to the fibre direction. The second phase occurs at temperatures between 60°C and 90°C where the shrinkage is parallel to the fibre axis. [1] This is supported by the studies on tenderness discussed in Section 4.2.1 which have found that the tenderness of meat decreases as the cooking temperature increases above 65°C.

Based on these findings, if sous vide products were to be produced with minimal yield losses as a key target, then processing temperatures less than 60°C should be considered. In this way, the second phase of water loss that occurs above 60°C will be avoided.

4.3 Chilling

In commercial kitchens and large scale operations blast chillers and chilled water immersion tanks are the most common technologies available in the market. These will be discussed in detail in Section 5 of this report.

4.3.1 Recommended storage conditions

The recommended storage period for sous vide cooked meat products is typically 21 days at 0°C to 3°C. These are the parameters suggested by SVAC and the NSW health Authority. [2,3] It is also imperative that products are cooled to below 3°C as quickly as possible to prevent the growth of bacteria. The lowest temperature for growth of one strain of Clostridium Botulinum is 3.3 °C, hence the maximum permissible storage temperature recommended is 3°C. [4] It is also recommended that it should take a maximum of two hours for the core temperature of the product to reach the storage temperature. [5] This may be difficult to achieve though with larger joints of meat. Figure 3 illustrates the effect of size and starting temperature on the core cooling time.

[1] Vaudagna, S. et al. (2002). Sous vide cooked beef muscles: effects of low temperature–long time (LT–LT) treatments on their quality characteristics and storage stability. *International Journal of Food Science and Technology*, 37, 425 – 441.

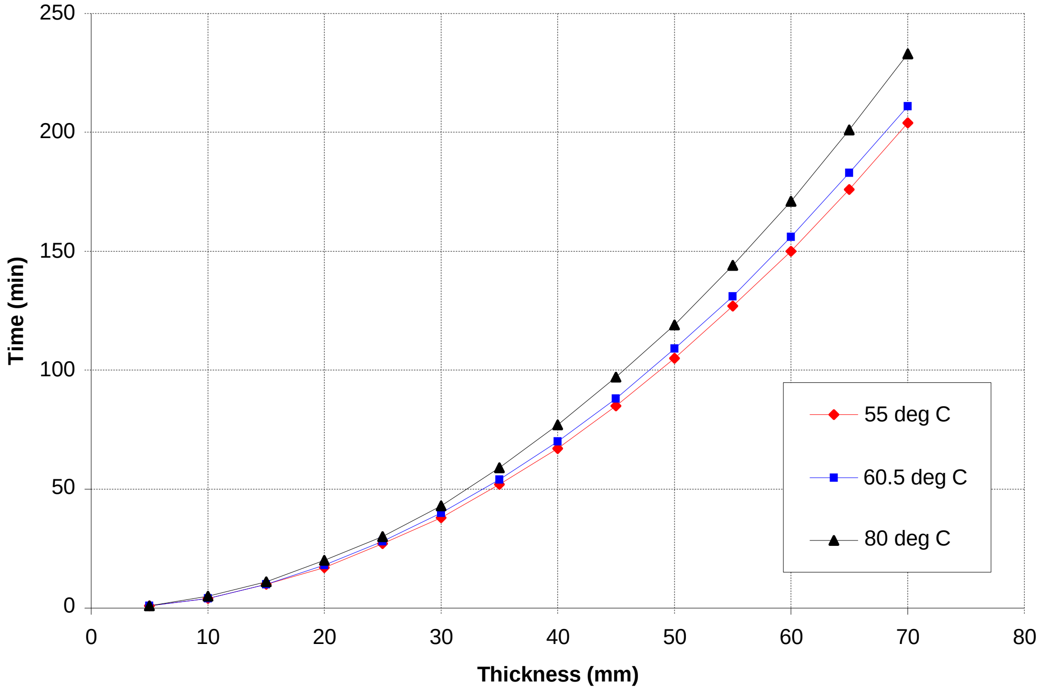
[2] NSW Food Authority. Vunerable Persons Food Safety Scheme Manual. Doc No. NSW/FA/CP005/0805. August 2008.

[3] Tansey. F. et al. (2005). Developing Sous Vide/Freezing Systems for Ready-Meal Components. Teagasc Agriculture and Food Development Authority. <http://www.teagasc.ie/research/reports/foodprocessing/4875/eopr4875.asp> Accessed 24/02/11.

[4] Creed, P. (2000). Sous Vide - An Overview of the Process. Teagasc Publications, Ready Meals Conference, 2000. <http://www.teagasc.ie/publications/readymeals2000/paper03.asp>. Accessed 22/02/11.

[5] Tiampo. J. (2006). Seal Appeal: The Nutrition, Food Safety, and Operational Benefits of Sous Vide. <http://www.techne-calibration.com/adminimages/Sous_Vide_Information(1).pdf> Accessed 20/02/11.

Figure 3: Approximate cooling times for the core temperature of meat to reach 5°C in an ice water bath at various starting temperatures [1]



Regulations with respect to chilling requirements will be very important as they will limit the types of products that can be commercially produced by sous vide. At this stage though, there does not appear to be a defined set of regulations for this process. Even amongst the Australian regulations the cooling times vary from 1.5 to 4 hours.

In its natural state i.e. a whole piece of meat, food borne pathogens will only be present on the outside surfaces. As such, the internal time/temperature cooling profile is only important in preventing surface temperature rise during temperature equalisation where the heat in the product is transferred through the product surface to the cooling medium. As such, products should remain in the post-pasteurisation chillers until thermal equalisation is attained. It should be noted that layered products that may include two or more steaks in a single vacuum bag present a need to ensure adequate temperature reduction at the thermal core and requires consideration in the product and packaging specifications.

It has been promoted by Byropin meats that products can remain in good condition after 6 months chilled storage. [2] However, this is on the basis that the product does not experience any thermal stress during cold storage and is not guaranteed by the supplier. Historically maintaining temperature stability within the range required has proven quite difficult to achieve through the cold chain logistics for commercial

[1] Baldwin, D. (2008). A Practical Guide to Sous Vide Cooking. <http://www.douglasbaldwin.com/sous-vide.html> Accessed 01/03/11.

[2] Byropin Meats Pty Ltd. (2005). Use by dates and shelf life, Issue 1, 12th October 2005. <http://www.bryopin.com.au/Publications/Microsoft%20Word%20-%20Use%20By%20dates.pdf> Accessed 17/02/11.

scale operations. [1] This combined with the relatively low cooking temperature of sous vide products raises key safety concerns for the process. These will be discussed in Section 7.

4.3.2 Safety issues and freezing

The safety issues associated with temperature abuse through the cold chain has resulted in some producers utilising freezing to guarantee the safety of their product. While freezing can extend shelf life and minimise the risk of growth of Clostridium botulinum spores, the formation and propagation of ice crystals through the tissue structure can damage the muscle fibres adversely affecting the finished product texture. Water losses during thawing result in a tougher end product which arguably negates the potential quality advantages of the sous vide process. [2] It is important to note however that freezing does not kill food borne pathogens, it only slows down the growth rate.

Tansey et al. (2005) studied the effects of freezing on sous vide beef and lamb shoulder. Taste panels were unable to detect a significant difference between chilled samples and short term frozen samples. The adverse effects of freezing on quality were more evident after long term frozen storage up to 8 months. [2] It should be noted though that the test products were diced and cooked at 90°C for 3 hours 20 minutes. This suggests that the products were likely to have been cooked medium to well done and hence quite tough to begin with. Further studies may be required to assess the effects of freezing on more tender medium rare sous vide products.

4.4 Finishing for Service

Finishing for service firstly involves reheating the sous vide products at a temperature equal to or below the pasteurisation temperature. Typically, in a commercial kitchen this is by means of a temperature controlled heated water bath i.e. a bench top sous vide cooker. Since sous vide is essentially a poaching process, red meat products typically required searing on a hot grill for meal presentation and to induce Maillard reactions and add flavour and texture to the surface. This finishing step not only adds flavour but also serves to kill off bacteria present on the surface of the meat. [3]

The accuracy of the temperature required in the reheating process means that the finishing kitchen will need to have a sous vide cooker or the like. However, this type of equipment is not likely to be available to the average consumer if sous vide products were to be available in the retail market. As such, retail products would require clear and concise finishing instructions. Byropin Meats, one of Australia's largest suppliers of sous vide cooked meat products, specify oven roasting to finish off their large joints of beef, lamb, pork and veal. The finishing roasting time and temperature is specified to caramelise the outer surface of the meat without unnecessarily overcooking the product. [4]

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[1] Creed, P. (2000). Sous Vide - An Overview of the Process. Teagasc Publications, Ready Meals Conference, 2000. <http://www.teagasc.ie/publications/readymeals2000/paper03.asp>. Accessed 22/02/11.

[2] Tansey. F. et al. (2005). Developing Sous Vide/Freezing Systems for Ready-Meal Components. Teagasc Agriculture and Food Development Authority. <http://www.teagasc.ie/research/reports/foodprocessing/4875/eopr4875.asp>. Accessed 24/02/11.

[3] Baldwin, D. (2008). A Practical Guide to Sous Vide Cooking. <http://www.douglasbaldwin.com/sous-vide.html> Accessed 01/03/11.

[4] Byropin Meats Pty Ltd. (2001). Company and Product Overview. <http://www.bryopin.com.au/Publications/Microsoft%20Word%20-%20Brown%20Doc%20in%20word.pdf> Accessed 17/02/11.

Other potential sous vide products may include individual steaks and stewed in the bag products such as beef osso bucco or lamb shanks. If developed for the retail market each type of product must have a carefully designed finishing process that can be undertaken in the typical household kitchen. There would be a need for an education process to be rolled out to ensure the safe finishing of the overall cooking process by the end consumer without unnecessarily overcooking the product and in turn destroying the sensory qualities gained through sous vide in the first place.

This raises questions with respect to the ability to market sous vide products as ‘quick meals’. There is no significant time saving advantage in the finishing times of sous vide products as compared to fresh meat. Consequently, the attraction will primarily be in the additional product offerings with sauces and the like and the tenderness or juicy appeal of the product. This will be discussed in Section 8.

5. Sous-Vide Processing Equipment

This section will provide an overview as to type of equipment available for sous vide processing and the likely sizing, costs and equipment capacities.

For the purposes of estimating equipment capacities and throughput, the equipment scoped in this study has been sized based on the production of 500 gram individual beef products vacuum sealed in 200 mm x 250 mm pouches. These products have been sized on the basis of providing a suitable retail pack. Please note that this study is limited to the processing equipment required from vacuum packing through to post-pasteurisation chilling. Building infrastructure costs have not been considered at this stage. It should also be noted that this study has been focused on commercial kitchen operations through to large scale manufacturing. Small scale bench top kitchen equipment has not been considered.

5.1 Vacuum Packaging

Vacuum packing machines are typically stand alone items consisting of an evacuation chamber and a sealing bar. Bagged products are manually laid out in the chamber with the chamber area and length of the sealing bar determining the number of products that can be sealed in one cycle. Air is extracted from the chamber and when a vacuum is reached the sealing bar closes to seal the plastic pouches. Production capacities are a function of the size and cycle time of the vacuum chamber.

Table 1 below summarises the production capacities and typical equipment costs for a variety of vacuum packaging machines. Further details including technical specifications, utilities requirements and local servicing are included in Appendix A. This study has only considered small to medium throughput equipment and has not included large rotary machines rated at 30 – 35 packs per minute.

Table 1: Capacity and Costs for Typical Vacuum Packaging Machines [1]

Manufacturer & Model	Processing Capacity	Equipment Cost (AUD ex GST)
Henkovac E-203	5 packs/min	$ 7,650
Vacutec EPX 70	8 – 10 packs/min	$ 11,500
Henkovac E-403	12 – 14 packs/min	$ 14,950
Vacutec EPX 85	16 – 20 packs/min	$ 15,500
Henkovac E-493	18 – 20 packs/min	$ 23,285
Vacutec EPX 165	20+ packs/min	$ 31,500

[1] These costs are estimates only for equipment and may not cover full project costs and therefore may not be relied on.

5.2 Pasteurisation and Chilling

5.2.1 Combination Ovens and Blast Chillers

Combination steam and forced convection (combi) ovens are commonly used in commercial kitchen operations and can be utilised for sous vide processes. In general, they are relatively cheap to install and require only power and mains process water. However, there has been some concern in the literature as to the performance of combi ovens in terms of maintaining a constant temperature throughout both the cooking cycle and spatially through the oven chamber. It should be noted that all of the models that we have obtained pricing for are accurate to within ±3°C of the temperature set-point. Considering the high degree of temperature sensitivity associated with sous vide cooking, this technology may not be appropriate. This will however depend on the product processed and the technical aspects of the recipe.

Sheard and Rodger (1995) assessed a variety of combi ovens in terms of their ability to deliver consistent heat treatment to vacuum sealed products. The results showed significant deviations from the temperature setpoint throughout the cooking cycle. In addition, at any given time during the cooking cycle there was a considerable range of temperatures throughout the volume of the cooking chamber, particularly when the ovens were fully loaded with product. It was suggested that the variations in heating times are largely a result of the dependence of condensing steam as the heat transfer medium. Intermittent inputs of steam used to maintain temperatures below 100°C result in poor heat distribution throughout the cooking chamber. [1]

Table 2 and Table 3 summarise the typical costs and production capacities for a variety of combi ovens and blast chillers. Further details including technical specifications, utilities requirements and local servicing are included in Appendix A. The cost of vacuum bags is approximately $0.1/bag.

Table 2: Capacity and Costs for Typical Combi Ovens [2]

Manufacturer & Model	Chamber Capacity	Approximate Batch Size	Equipment Cost (AUD ex GST)
Angelo Po Combistar FX101E3	10 x GN 1/1 containers	120 portions	$27,500
Rational CombiMaster 102E	20 x GN 1/1 containers	225 portions	$30,000
Angelo Po Combistar FX202E3	40 x GN 1/1 containers	450 portions	$56,560
Rational CombiMaster 202E	40 x GN 1/1 containers	450 portions	$58,500

Table 3: Capacity and Costs for Typical Air Blast Chillers [2]

Manufacturer & Model	Cycle Time	Approximate Batch Size	Equipment Cost (AUD ex GST)
Angelo Po IS101SR	42 kg of product from +90° C to +3°C in 90 minutes	120 portions	$17,200
Angelo Po ISR202R	210 kg of product from +90° C to +3°C in 90 minutes	450 portions	$60,045

[1] Sheard. M. & Rodger. C. (1995). Optimum heat treatments for 'sous vide' cook-chill products. *Food Control*, 6, 53 – 56.

[2] These costs are estimates only for equipment and may not cover full project costs and therefore may not be relied on.

5.2.2 Cook – Chill Tanks

Cook – Chill tanks are essentially large cooking vessels that are able to cook and chill vacuum sealed products using water immersion cooking and chilling. In general these are relatively more expensive to install and set up compared with combi ovens. However, cook – chill tanks provide greater accuracy of temperature control and hence quality assurance as well as larger batch sizes. Typically they require steam, glycol and compressed air utilities in addition to power and mains process water which adds significantly to the initial capital costs. Note that the various cook-chill tank models that we have obtained pricing for are accurate to within ±0.5°C to ±2°C of the temperature set-point.

Vacuum sealed products can be loaded into large basket/racks that can later be transported to the processing area and hoisted into the cook tanks. An overhead hoist and monorail is usually installed to transfer batches of product into and out of the cook-chill tanks.

Table 4 and Table 5 summarise the typical costs and production capacities for a variety of cook-chill tanks and associated equipment. Further details including technical specifications, utilities requirements and local servicing are included in Appendix A.

Table 4: Capacity and Costs for Typical Cook-Chill Tanks [1]

Manufacturer & Model	Chamber Capacity	Approximate Batch Size	Equipment Cost
DC Norris CTTC-100 Cook Tank Tumble Chiller	Rated for 225 kg of product per batch.	450 portions	$ 110,830
CapKold by Groen CKCT-10 Automatic Cook Chill Tank	Rated for 450 kg of product.	900 portions	$124,925 (comes with basket/rack set and trolley)
Sepak Industries BP600 Batch Pasteurisation System	Rated for 600 kg of product per batch.	1200 portions	$65,880 (ex works equipment cost only. Includes 1 basket set)
Sepak Industries BP800 Batch Pasteurisation System	Rated for 800 kg of product per batch.	1600 portions	$85,880 (ex works equipment cost only. Includes 1 basket set)
DC Norris CT-20 Cook/Chill Tank	Rated for 900 kg of product per batch.	1800 portions	$ 116,025 (includes 1 basket set)

Table 5: Typical Ancillary Equipment Costs for Cook-Chill Tanks [1]

Item	Equipment Cost (AUD ex GST)
Baskets and rack unit for loading products and hoisting (dependant on the size of the tank)	$5,880 – $11,865 each
Trolley for transport of loaded baskets/rack	$2,225 – $3,980 each
Monorail and hoist for loading baskets/rack (dependant on the size of the tank)	$15,000 – $61,835

[1] These costs are estimates only for equipment and may not cover full project costs and therefore may not be relied on.

6. Production Line Marginal Costing Estimates

This section of the report will provide an overview of typical equipment and operating costs in setting up a production line based on nominated throughput rates. Equipment has been sized based on the production of 500 g individual beef products vacuum sealed in 200 mm x 250 mm pouches and cooked over 24 hours. An 8 hour day shift for operations staff has been assumed as the working time available.

As previously noted this study is limited to the processing equipment required from vacuum packing through to post-pasteurisation chilling. Building infrastructure costs such as raw materials and finished goods cold storage have not been considered at this stage. We have also assumed that process water and compressed air services will be already installed at the processing facility. Essentially this study has only considered the marginal cost of sous vide processing whereby a sous vide production line is incorporated into an already established food processing facility.

It should be noted that the costs of the vacuum bags (approximately $0.1/bag) have been excluded from the marginal cost estimates. It is assumed that this is a neutral cost in that product packaging will be required regardless of whether the product is sous vide, fresh meat or any other meat product. This allows a comparison in Section 8 between current fresh meat products and the added cost of sous vide processing.

Note that equipment prices are based on supplier pricing that we have obtained and also Rawlinsons Australian Construction Handbook 2011. [1]

For the purposes of estimating operating costs the following utilities rates have been adopted:

- Gas – 1.8c/MJ;
- Power – 10c/kWh (rate estimated to allow for the reduced off peak rates during overnight cooking); and
- Water – $2/kL.

6.1 1800 portions/day throughput using combi ovens

In this scenario four off 450 portion Angelo Po Combistar FX202E3 combi ovens are operated in series with approximately two hours phase separation between the cooking start times. One 450 portion Angelo Po ISR202R blast chiller would be required which would be utilised throughout the eight hour shift as each batch is cooked and taken to the chiller. Six off stainless steel product racks are estimated to be required. These would be loaded in the vacuum packing room and wheeled into the combi oven and then later into the blast chiller. At any time one rack would be being loaded, three racks would be in the ovens, one in the chiller and one being unloaded in the finished goods cool room.

The packing rate required to keep up with the process would have to deliver 450 packs every two hours, giving just under 4 packs per minute. In order to free up part of the operators working time for other tasks such as cleaning, the Vacutec EPX 70 would be appropriate which can deliver 8 – 10 packs per minute.

[1] Rawlinsons Australian Construction Handbook. (2011). Ed 29. Rawlinsons Publishing, Perth, WA.

The packaging area would be within a dedicated cool room maintained at a setpoint between 3°C and 10°C.

Three operators are estimated to be required, one vacuum packing, one cooking and cleaning the ovens and one loading and unloading products onto the racks.

Figure 4 illustrates the process in this scenario. Table 6 provides a summary of the key costs for setting up and operating this production line. Detailed calculation spreadsheets are included in Appendix B for reference.

Figure 4: 1800 Portion/Day Combi Oven Production Line Flowchart

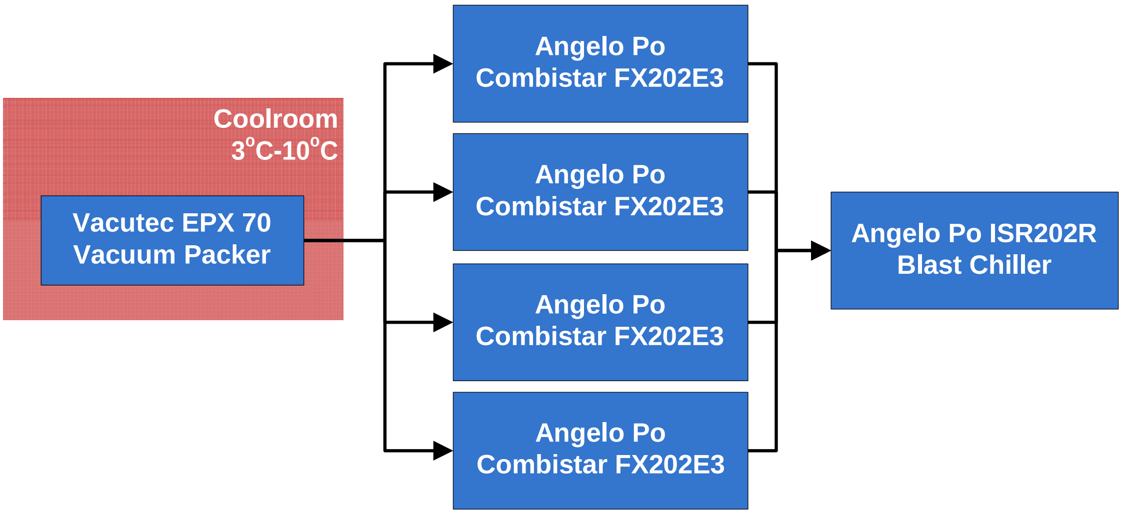


Table 6: 1800 Portion/Day Combi Oven Production Line Key Costs

Item	Cost
Total capital equipment costs	$328,960
Total operating costs per day	$1,565
Cost of sous vide process per pack	**$1.04**
Cost of sous vide process per kg	**$2.07**

6.2 1800 portions/day throughput using cook-chill tanks

In this scenario two off 900 portion CapKold CKCT-10 cook-chill tanks are operated in series with approximately three hours phase separation between the cooking start times. Four off stainless steel product racks are estimated to be required each with its own trolley. At any time one rack would be being loaded, two racks would be in the cook-chill tanks, and one would be being unloaded in the finished goods cool room.

A hoist and monorail extending over the two cook-chill tanks would also be required to load the product racks into and out of the cook-chill tanks.

The packing rate required to keep up with the process would have to deliver 900 packs every three hours, giving 5 packs per minute. In order to free up part of the operators working time for other tasks such as cleaning, the Vacutec EPX 70 would be appropriate which can deliver 8 – 10 packs per minute. The packaging area would be within a dedicated cool room maintained at a setpoint between 3°C and 10°C.

Two operators are estimated to be required, one vacuum packing and loading product onto the racks and one maintaining the cook-chill tanks and unloading the finished product.

Although it is possible to produce 1800 portions in a single batch of a larger cook tank, it is beneficial in terms of operations to maintain a steady flow of finished goods from the factory. Having two separate cook tanks also gives the flexibility to produce different products during the same shift.

Figure 5 illustrates the process in this scenario. Table 7 provides a summary of the key costs for setting up and operating this production line. Detailed calculation spreadsheets are included in Appendix B for reference.

Figure 5: 1800 Portion/Day Cook-Chill Tank Production Line Flowchart

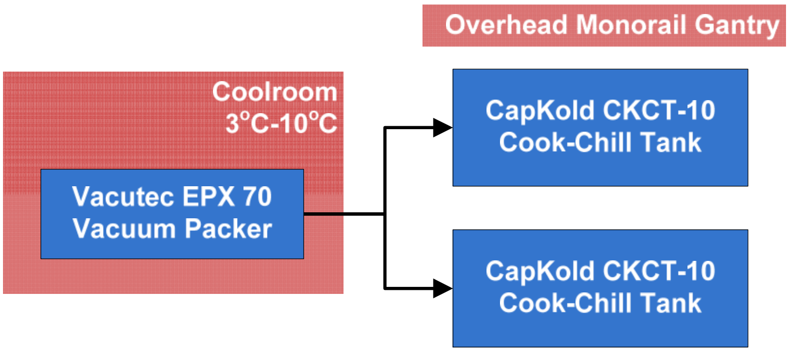


Table 7: 1800 Portion/Day Cook-Chill Tank Production Line Key Costs

Item	**Cost**
Total capital equipment costs	$301,388
Total operating costs per day	$1,018
Cost of sous vide process per pack	**$0.72**
Cost of sous vide process per kg	**$1.44**

6.3 5400 portions per day using cook and chill tanks

In this scenario three off 1800 portion DC Norris CT-20 dedicated cook tanks are operated in series with approximately two hours phase separation between the cooking start times. After each batch the products would be cooled in a separate dedicated DC Norris CT-20 chill tank which would be utilised throughout the day. Five off stainless steel product racks are estimated to be required. At any time one rack would be being loaded, three racks would be in the cook and chill tanks, and one would be being unloaded in the finished goods cool room. A hoist and monorail extending over the three cook tanks and dedicated chill tank would also be required to load the product racks into and out of the cook-chill tanks.

The packing rate required to keep up with the process would have to deliver 1800 packs every two hours, giving 15 packs per minute. In order to free up part of the operators working time for other tasks such as cleaning, the Vacutec EPX 165 would be appropriate which can deliver 20+ packs per minute. The packaging area would be within a dedicated cool room maintained at a setpoint between 3°C and 10°C.

Four operators are estimated to be required, one dedicated to vacuum packing products, one to load products onto the racks, and two operators maintaining the cook and chill tanks and unloading the finished product. Figure 6 illustrates the process in this scenario. Table 8 provides a summary of the key costs for setting up and operating this production line. Detailed calculations are included in Appendix B for reference.

Figure 6: 5400 Portion/Day Cook and Chill Tank Production Line Flowchart

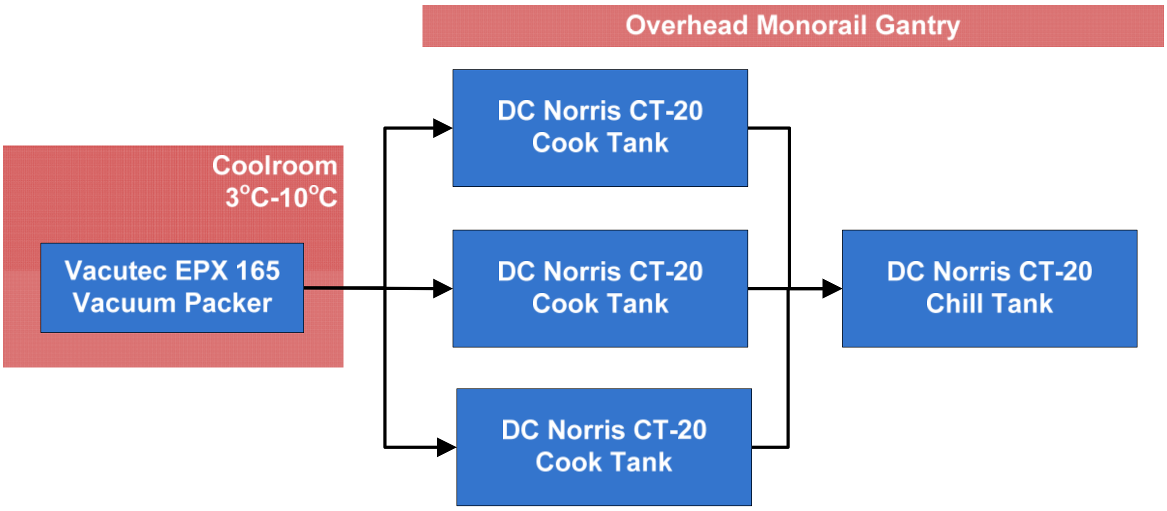


Table 8: 5400 Portion/Day Cook and Chill Tank Production Line Key Costs

Item	Cost
Total capital equipment costs	$690,425
Total operating costs per day	$2,002
Cost of sous vide process per pack	**$0.49**
Cost of sous vide process per kg	**$0.98**

6.4 Additional Factors for Consideration

The costs associated with Quality Assurance procedures would are also of particular concern with sous vide processes. The process requires a high degree of temperature control but does not allow the core temperature of the product to be tested non-invasively. As such, it would be critical to calibrate temperature sensors and other equipment on a daily basis which would incur ongoing maintenance costs.[1]

The option to sell sous vide products at retail in their vacuum bags will remove the meat tray packing and packaging costs that are associated with conventional cook – chill processing methods. These costs would be in the order of $0.5/pack. This in addition to the retention of product yield could potentially create an uplift in the quality/price point for primal cuts that are commercially processed by sous vide.

It should be noted that for the concept production lines previously discussed, additional capital expenditure would be required in order to scale up operations to two production shifts. The simulations based on an 8 hour shift over the course of which each batch finished and replenished in each cook tank or oven. Increasing production in this case is not simply a matter of adding another 8 hourr night shift as there will not be any spare capacity in the cooking vessels. Additional cooking vessels will be required to match the additional production. However, the vacuum packers and chillers could be utilised in the second shift. In any case, sous vide processing would require operating times to be scheduled according to the requirements of the production orders. For example, campaign runs of long cook time products may only necessitate a skeleton crew whereas shorter production runs of various different products may require a fully staffed operation.

[1] Tiampo. J. (2006). Seal Appeal: The Nutrition, Food Safety, and Operational Benefits of Sous Vide. <http://www.techne-calibration.com/adminimages/Sous_Vide_Information(1).pdf>. Accessed 21/02/11.

7. Food Safety and Risk Analysis

Section 4 of this report has touched on some of the safety issues associated with sous vide cooking and the subsequent cold chain storage of the product. These safety issues and their implications to commercial scale manufacturing of sous vide products will be discussed in this section of the report along with relevant regulations and industry best practices and the controls and risk management procedures that can be employed to minimise these safety risks.

7.1 Summary of Key Safety Issues

The key safety issues associated with commercial sous vide production are as follows:

1. Vacuum packaging creates ideal environment for the propagation of anaerobic pathogens. Of these, Clostridium botulinum is of particular concern due to its toxicity and resistance to heat treatments.
2. The relatively low temperature nature of sous vide pasteurisation processes combined with the anaerobic conditions of the packaging provide an ideal environment for the propagation of Clostridium botulinum and other anaerobic pathogens.
3. The shelf life and safety of commercial sous vide products is greatly affected by thermal stresses experienced throughout the cold chain. The lowest temperature for growth of one strain of Clostridium Botulinum is 3.3°C. [1] Hence, the storage temperature recommended must be in the range of 0°C to 3°C. Historically, this has proven quite difficult to achieve through cold chain operations.
4. Finishing for service procedures are often utilised to kill off pathogens present on the surface of the meat. For the commercial food service market, this process would be controlled by an appropriately skilled chef. However, the challenge for the retail market is ensuring that finishing procedures are undertaken correctly by untrained consumers.

Rodgers (2005) suggests that a lack of confidence in food safety and the limitations of chilled distribution channels combined with over-conservative regulations are key factors that have prevented the widespread adoption of sous vide and other cook-chill products in the Australian food service and retail markets. [2] Consequently, out of the small sous vide market that currently exists, products are often frozen. This is the case for Prepared Foods Australia (formerly Eurest Prepared Foods) (Discussed in Section 8.1).

In the UK approximately 80% of sous vide products are frozen. The longest established UK manufacturer, Thomas Morel produces both frozen and chilled sous vide products. However, their core business is braised and stewed products that lend themselves to a more intense pasteurisation process without adversely affecting product quality. This offers Thomas Morel a margin of safety of the minimum

[1] Creed, P. (2000). Sous Vide - An Overview of the Process. Teagasc Publications, Ready Meals Conference, 2000. <http://www.teagasc.ie/publications/readymeals2000/paper03.asp>. Accessed 22/02/11.

[2] Rodgers, S. (2005). Food safety research underpinning food service systems – a review. *Food Service Technology*, 5, 67 – 76.

which in turn minimises customer fears over food safety. [1] It is important to note however that freezing does not kill food borne pathogens, it only slows down the growth rate.

A notable case study from the US is that of Culinary Brands which produced sous vide products on a commercial scale from their facility in California. Upon expanding their operations to supply clients on the east coast, the costs of ensuring continuity through the supply chain became too great rendering the operation unprofitable. Culinary Brands soon moved toward freezing sous vide products in order to supply the wider US market. [1]

Despite this history, there is potential for the development of the sous vide market at both a retail level and food service level provided that appropriate risk management strategies and procedures are in place as discussed in Section 7.4.

7.2 Relevant Regulations and Codes of Practice

In 1992 the Australian Quarantine and Inspection Service (AQIS) developed a Code of Hygienic Practice for Heat-treated Refrigerated Foods Packaged for Extended Shelf Life. The AQIS code of practice drew heavily on UK guidelines; in particular the recommendations made in a 1992 report on vacuum packing and associated processes by the UK Advisory Committee on Microbiological Safety of Food (ACMSF).

The Australian Institute of Food Science and Technology (AIFST) has also developed a 2000 guideline entitled ‘Cook Chill for Foodservice and Manufacturing: Guidelines for Safe Manufacturing, Storage and Distribution’. This is commonly referred to as the Blue Book. Peck et al. (2006) suggest that this guideline is designed to apply to the catering sector rather than retail and hence it is not believed to be complied with in the retail sector. [2]

In the UK, the Campden and Chorleywood Food Research Association (CCFRA) developed a 1996 Code of practice for the manufacture of vacuum and modified atmosphere packaged chilled foods with particular regard to the risks of botulism. This was based on the ACMSF 1992 report and statutory temperature controls in England, Wales and Northern Ireland.

Essentially all of these standards and guidelines are very similar in their recommendations for pasteurisation, post process chilling and storage of sous vide products. Minimum cooking and chilling parameters are prescribed based on a desired shelf life for the product. A summary of the key recommendations of each guideline or code is provided in Table 9.

[1] Creed, P. (2000). Sous Vide - An Overview of the Process. Teagasc Publications, Ready Meals Conference, 2000. <http://www.teagasc.ie/publications/readymeals2000/paper03.asp>. Accessed 22/02/11.

[2] Peck, M.W. et al. (2006). Clostridium botulinum in vacuum packed (VP) and modified atmosphere packed (MAP) chilled foods. <www.avhic.com/wp-content/uploads/.../a_clostridiumm-in-vacuum11.pdf> Accessed 01/04/11.

Table 9: Sous vide processing regulations and codes of practice [1,2,3,4]

Reference	Pasteurisation	Post Process Chilling	Chilled Storage	Shelf Life
AQIS 1992 (Australia)	Equivalent time-temperature process to achieve a 6D reduction of the target organism (L.monocytogenes or C.botulinum).	Chilling to start within 30 mins. Core to reach storage temperature within 4 hours.	≤3°C for extended shelf life. Max 5 days shelf life if >5°C. Discard product if product >10°C.	>5 days if ≤3°C. If ≤5°C eat within 10 days of purchase unless frozen.
AIFST 2000 (Australia)	Time-temperature process equivalent to 70°C for 2 mins or 90°C for 11 mins according to the recipe.	Chilling to start within 30 mins. Chill to 3°C within 90 mins.	-1°C to 3°C.	Suggests that some products can achieve up to 45 days shelf life. This must be based on quality and microbial testing.
FSANZ (Australia and New Zealand)	No specific requirements. Note that FSANZ regulations only state cooked meats and do not specify requirements for sous vide products.	For cooked meats, cooling from 60°C to 21°C within 2 hours and from 21°C to 5°C within a further 4 hours.	The total time that a ready-to-eat potentially hazardous food can be at temperatures between 5ºC and 60ºC is 4 hours.	Specific requirements for sous vide products not stated.
NSW Food Authority 2008	Short life cook-chill foods: 70°C for 2 mins or equivalent process to achieve a 6 log reduction in L.monocytogenes	3°C within a max time of 150 mins from the end of the cooking cycle allowing for 30 mins delay.	3°C	5 days maximum including the date of production.
NSW Food Authority 2008	Extended life cook-chill foods: 90°C for 10 mins or equivalent process to achieve a 6 log reduction for non-proteolytic C.botulinum.	Max core temperature of 3°C within a max time of 90 mins from the end of the cooking cycle.	≤10 days shelf life at 5°C storage. 21 - 28 days shelf life at 0°C to 3°C storage.	
ACMSF 1992 (UK)	Heat treatment of 90°C for 10 mins or equivalent lethality for products with >10 days shelf life. If not heated to 90°C/10 mins equivalent, use at least 1 hurdle to Prevent the growth and toxin formation by non-proteolytic C. botulinum	Not specified.	8°C	10 days max at 8°C unless non-proteolytic C. botulinum control in place in addition to chill.
CCFRA 1996 (UK)	70°C/2 mins or equivalent process for ≤10 days shelf life. 90°C/10 mins or equivalent process for >10 days shelf life. If not heated to 90°C/10 mins equivalent then at least 1 hurdle is required.	Chilling to start within 30 mins. Portion size packs to be chilled to 5°C in 90 mins. Large size packs to be chilled from 50°C to 10°C in 4 hours.	≤3°C pre distribution/retail storage temperature. 8°C retail storage.	Dependant on the pasteurisation process as outlined. Short shelf life ≤10 days. Long shelf life >10 days.
SVAC 1991 (UK)	Targeting non-proteolytic C. botulinum, time-temperature process equivalent to 90°C for 10 mins.	Chilling to start within 30 mins. Chill to 3°C within 90 mins.	0°C to 3°C.	8 days maximum.

[1] NSW Food Authority. Vunerable Persons Food Safety Scheme Manual. Doc No. NSW/FA/CP005/0805. August 2008.

[2] Peck, M.W. et al. (2006). Clostridium botulinum in vacuum packed (VP) and modified atmosphere packed (MAP) chilled foods. <www.avhic.com/wp-content/uploads/.../a_clostridiumm-in-vacuum11.pdf> Accessed 01/04/11.

[3] Dick, H.M. et al. (1992). Advisory Committee on the Microbiological Safety of Food (ACMSF). Report on Vacuum Packaging and Associated Processes. London: HMSO.

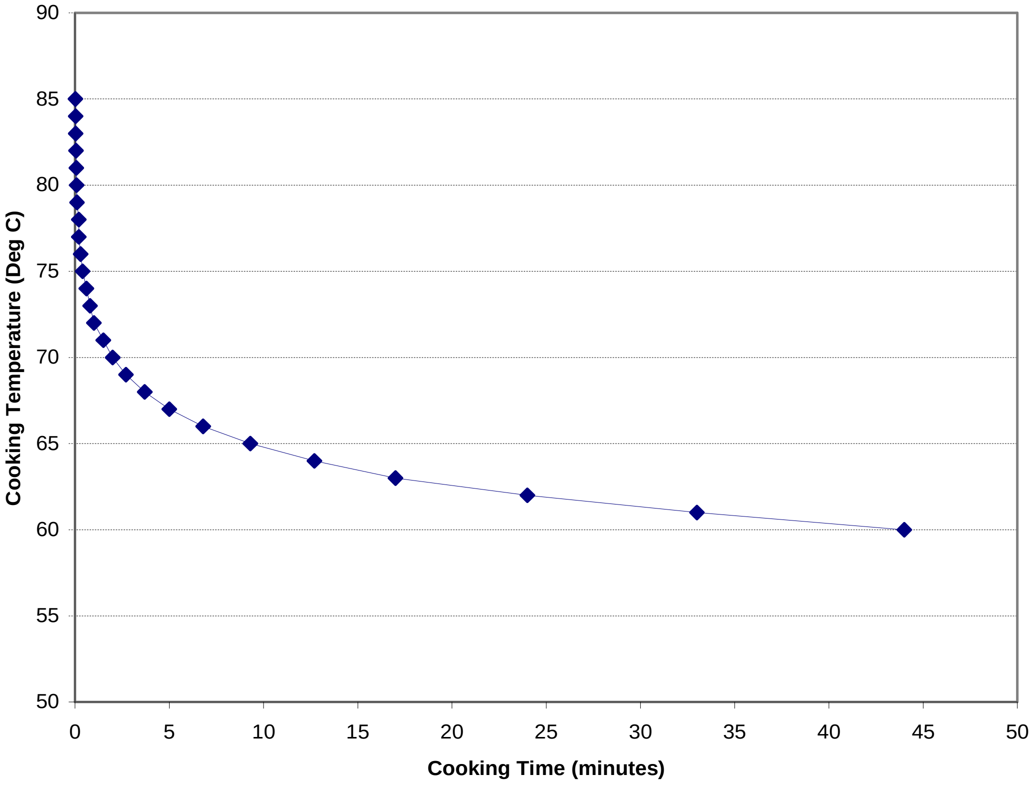
[4] Food Safety Programs: A guide to Standard 3.2.1 Food Safety Programs. Chapter 3 of the Australia New Zealand. Food Standards Code (Australia only), 1st ed, June 2007.

Reference	Pasteurisation	Post Process Chilling	Chilled Storage	Shelf Life
FDA CFSAN 2005 (USA)	Various mild processes ranging from 54.4°C for 112 mins to 70°C for 0 mins (instantaneous). Other hurdles are specified, A_w≤0.91 and pH≤0.46.	Cooled to 5°C and then cooled to ≤-1°C within 48 hours of reaching 5°C.	1°C maximum storage temperature.	30 days maximum.

7.3 Equivalent Time-Temperature Pasteurisation Profiles

It is important to note from the pasteurisation requirements summarised in Table 9, the nature of the equivalent time-temperature processes specified. These are illustrated in Figure 7 and Figure 8.

Figure 7: Equivalent 6D Time-Temperature Combinations for Spores of L.monocytogenes [1,2,3]



[1] NSW Food Authority. Vunerable Persons Food Safety Scheme Manual. Doc No. NSW/FA/CP005/0805. August 2008.

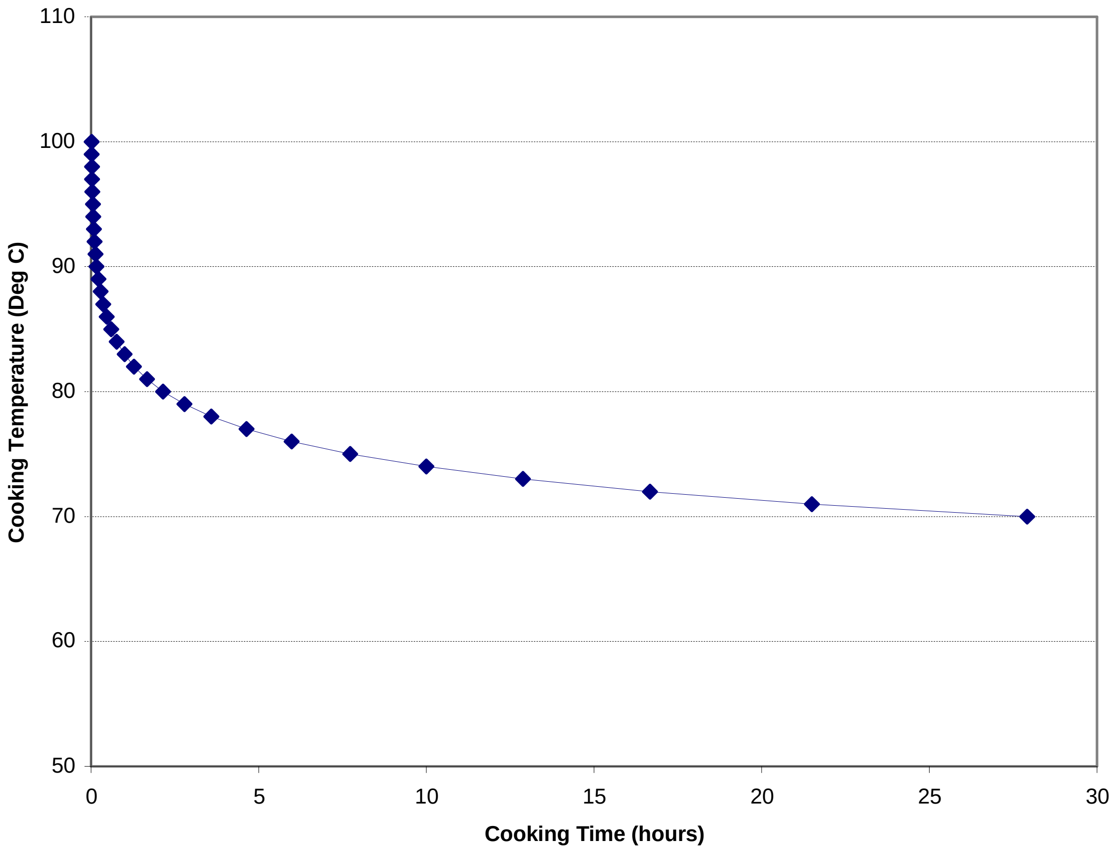
[2] NSW Food Authority. Listeria Management Program. Doc No. NSW/FA/FI034/0809.

[3] The curve in Figure 7 was produced from data points given in Sources noted in footnotes 1 and 2. The curve shows indicative time-temperature combinations to achieve a 6-log reduction in Listeria monocytogenes. Actual time-temperature combinations may be process specific and as such microbiological testing would be required to confirm the lethality of the heat treatment.

Figure 7 illustrates the time temperature combinations equivalent to 2 minutes at 70°C to achieve a 6D reduction in Listeria monocytogenes. In microbiology the D-value or decimal reduction time is the time required at a specified temperature to kill 90% of the target organisms.

This pathogen is of particular concern in chilled foods because of its ability to propagate at temperatures close to freezing and at a wide range of pH and water activity (A_w) values. As such, L.monocytogenes has become the target pathogen stated in the regulations for short shelf life products of typically less than 5 days storage. [17]

Figure 8: Equivalent 6D Time-Temperature Combinations for Spores of Psychrotrophic C. Botulinum [1,2,3]



[1] Dick, H.M. et al. (1992). Advisory Committee on the Microbiological Safety of Food (ACMSF). Report on Vacuum Packaging and Associated Processes. London: HMSO.

[2] Food Standards Agency UK. Vacuum Packing and Modified Atmosphere Packing of Food – Online Training Course. <http://vacuumpackingtraining.food.gov.uk/introduction/> Accessed 31/03/11.

[3] The curve in Figure 8 was produced from data points given in Sources noted in footnotes 1 and 2. The curve shows indicative time-temperature combinations to achieve a 6-log reduction in Clostridium botulinum. Actual time-temperature combinations may be process specific and as such microbiological testing would be required to confirm the lethality of the heat treatment.

Figure 8 illustrates the time temperature combinations equivalent to 10 minutes at 90°C to achieve a 6D reduction in Clostridium botulinum. For extended shelf life sous vide products (>10 days) this is the most widely recommended pasteurisation process from the Australian and UK codes.

It should be noted however that for the optimum cooking temperature range of 50°C to 65°C for beef discussed in Section 4.2.1, achieving an equivalent 90°C/10 min process is not likely to be feasible. If the curve in Figure 8 were to be extrapolated below 70°C the equivalent cooking times may be too long to achieve practically. Furthermore extended cooking times in excess of two days can adversely affect product quality by over tenderising resulting in a mushy texture. However, some regulations (ACMSF 1992 and CCFRA 1996) have made provisions for cases such as these and allow the reduction of C. botulinum by other means known as hurdles if the equivalent time-temperature process is not achieved. These hurdles and other alternative risk management measures are discussed in the next section of the report.

In a recent discussion with representatives from sous vide cook-chill tank manufacturer DC Norris, GHD were advised that due to safety precautions they used a minimum of 70°C in the preparation of sous vide beef products. It should be noted though that this temperature setting was used to produce high end cuts of meat for business and first class airline meals and other food service applications. From the curve in Figure 8, 70°C appears to be the lowest acceptable cooking temperature before the cooking time becomes excessively long. The cooking temperature utilised in DC Norris' application may have been selected for the purposes of satisfying the minimum safety requirements rather than optimising product quality. Rodgers (2005) questions the 'over conservative' nature of the regulations and discuss this as a factor that restrains the widespread adoption of the sous vide process in the Australian food industry. [1]

7.4 Risk Management

Traditionally, the safety risks associated with sous vide processing have been managed by adjusting the shelf life accordingly to allow an adequate factor of safety considering the pasteurisation process and cold storage conditions. Critical Control Points (CCPs) specific to the sous vide production process and subsequent cold chain have been identified and are discussed in Section 7.4.1.

In addition to the typical operations and logistics controls, a review of the literature has indicated that there is potential for use of additional preservation factors known as hurdles[2] to provide additional food safety confidence and extended the allowable shelf life. These are discussed in Section 7.4.2.

Sterilisation technologies such as High Pressure Processing (HPP) and irradiation have also been suggested as end of line processes applicable to sous vide products.

7.4.1 Operations and Logistics Controls

Under Australian law all commercial food processing operations are required to develop a Hazard Analysis and Critical Control Point (HACCP) plan and sous vide processing is no exception. A HACCP

[1] Rodgers, S. (2005). Food safety research underpinning food service systems – a review. *Food Service Technology*, 5, 67 – 76.

[2] In food microbiology the term 'hurdle' is used to describe the combined application of food preservation factors to achieve microbiological safety

plan is intended to define the specific CCPs for biological, chemical and physical hazards and their particular control and monitoring requirements as applied to a particular processing operation. [1]

Raw Materials CCP

It goes without saying that quality and fresh raw ingredients are paramount to the quality of the end product as they are usually the principal source of pathogenic microorganisms. In terms of managing this, raw materials should be purchased to agreed specifications from audited suppliers. Upon receipt, raw materials should be checked against the agreed acceptance criteria which should include testing the base level count of surface bacteria present. [1, 2] Procedures should be in place to open raw ingredients packaging in a hygienic manner such that pathogens present on the surface of the packaging do not contaminate the product. Vaudanga et al. (2002) also suggested that at the product development stage, sous vide processing should consider the heat sensitivity and inherit microbiological risk of the raw meat product which can vary. [3] It should also be noted that sous vide processing is not recommended for reformed meat products.

Product Assembly and Vacuum Packing CCP

A segregated and hygienic product preparation area would be required in a commercial sous vide processing facility. Because of the batch nature of the sous vide process, there would be an extensive product holding time as an operator vacuum seals each portion and stacks them in the cooking vessel rack. In the simulations outlined in Section 6, this holding time was 1 – 2 hours. As a result the working environment would need to be maintained between 3°C and 10°C. An alternative to this may be the installation of holding chillers in the product assembly area.

Portion size control would also be critical as this is essential is the cooking process is be effective and consistent on product quality and microbiological safety. [1] As with any food preparation area, cleaning, sanitation and hygienic procedures need to be suitably incorporated into the operating procedures. [4]

Pasteurisation CCP

The heat treatment applied to sous vide products is critical in ensuring their microbiological safety as well as their sensory quality. The process requires a uniform and consistent heat load applied to all pouches in each batch. Core temperatures of the product cannot be measured noninvasively. As such temperature regulation instruments and sensors must be calibrated regularly and cooking medium temperatures must be recorded throughout each batch.

It has also been shown that the rate of heating affects pathogenic survival in sous vide processing. Juneja and Marks (2003) showed that salmonella survival rates in sous vide cooked beef increased as the rate of heating decreased i.e. the thermo-tolerance of surface Salmonella increased in samples

[1] Baird-Parker, A.C. (1994). Use of HACCP by the chilled food industry. *Food Control*, 5, 167 – 170.

[2] Nissen, H. et al. (2002). Safety evaluation of sous vide-processed ready meals. *Letters in Applied Microbiology*, 35, 433 – 438.

[3] Vaudagna, S. et al. (2002). Sous vide cooked beef muscles: effects of low temperature–long time (LT–LT) treatments on their quality characteristics and storage stability. *International Journal of Food Science and Technology*, 37, 425 – 441.

[4] Tansey. F. et al. (2005). Developing Sous Vide/Freezing Systems for Ready-Meal Components. Teagasc Agriculture and Food Development Authority. <http://www.teagasc.ie/research/reports/foodprocessing/4875/eopr4875.asp>. Accessed 24/02/11.

where the temperature of the cooking medium was slowly increased from 10°C to the cooking temperature setpoint of 58°C. [1] Tansey et al. (2005) also suggested a similar heat stress relationship. [2] Hence, a critical control of the process would be ensuring that the cooking vessel/cooking medium is pre heated to the specified cooking temperature before the raw products are placed in the vessel.

Post Processing Chilling and Cold Chain CCPs

Similarly to the cooking vessel the post processing blast chiller or chilled water vessel must have the appropriate instruments and procedural checks to ensure uniform and consistent heat load.

Transport and distribution is a very crucial step in the process due to the risk of potential thermal stress through the cold chain. [2] Transportation vehicles and retail cabinets should maintain a consistent temperature within the range of 0°C and 3°C. [3] Data loggers would be recommended for the trucking compartments as well as a set of requirements established for the allowable time-temperature variance whilst still maintaining acceptable product quality.

7.4.2 Hurdles

In food microbiology the term 'hurdle' is used to describe the combined application of food preservation factors to achieve microbiological safety. Typical hurdles used in food preservation include: [4]

- Addition of antimicrobials and competitive microorganisms;
- Additives that modify acidity (pH);
- Additives that modify water activity (A_w); and
- Spices.

In general, there is a longstanding history of the successful use of hurdle techniques in the food industry. However, a review of the literature has revealed that further work is required to fully understand if these techniques would be effective in minimising pathogen counts in the production of sous vide meat products. In addition, there does not appear to be any literature on the effects of different hurdles on the sensory properties of the end product. As such this would need to be investigated for sous vide processing. A summary of some of the key hurdles used in the food industry is provided below.

Water Activity (A_w)

Water activity (A_w) is essentially a measurement of the energy status of the water in a system. Water binding chemicals, such as salts and sugars, can be used to remove the available water from a food to a point that micro-organism growth is inhibited. [1]

[1] Juneja, V.K. and Marks, H.M. (2003). Characterizing asymptotic D-values for Salmonella spp. subjected to different heating rates in sous-vide cooked beef. *Innovative Food Science and Emerging Technologies*, 4, 395 – 402.

[2] Tansey. F. et al. (2005). Developing Sous Vide/Freezing Systems for Ready-Meal Components. Teagasc Agriculture and Food Development Authority. <http://www.teagasc.ie/research/reports/foodprocessing/4875/eopr4875.asp>. Accessed 24/02/11.

[3] Baird-Parker, A.C. (1994). Use of HACCP by the chilled food industry. *Food Control*, 5, 167 – 170.

[4] Zhu, M. et al. (2005). Control of Listeria monocytogenes Contamination in Ready-to-Eat Meat Products. *Comprehensive Reviews in Food Science and Food Safety*, 4, 34 – 42.

At ambient temperatures the growth limiting salt concentration psychrotrophic Clostridium botulinum is approximately 5%. At storage temperatures below 10°C this growth limit is reduced to 3.5% in the aqueous phase. [2] Bolton (1998) obtained promising results using sodium lactate as a hurdle in sous vide processed beef mince. Growth was analysed at a storage abuse temperature scenario of 10°C. Considerable growth of L.monocytogenes and Y.enterocolitica was detected in the absence of sodium lactate but not when the salt was added. [3] However, the effect of this on both the survival of C.botulinum and product quality needs to be examined. At high concentrations a salty taste was evident in the samples with the salt added. If this were applied to the commercial production of sous vide meat products salt additions may impede on the potential health benefits and possible attainment of heart tick approval for sous vide products.

ACMSF (1992) recommends that for chilled foods with an assigned shelf life of over 10 days, a minimum salt level of 3.5% in the aqueous phase and $A_w \leq 0.97$ should be achieved throughout the product. [2]

Acidity

The minimum pH reported as permitting the growth of Clostridium botulinum is 5.0. Upper pH limits of Clostridium botulinum growth are in the range of 8-9 and are of no practical use in food. [2] Organic acids such as acetic, lactic and citric acids are often used as preservatives in the food industry.

Mbandi and Shelef (2001) showed that bacterial growth in beef samples could be suppressed with the addition of salts combined with a lowered pH. Combinations of sodium lactate and sodium diacetate suppressed the growth of L.monocytogenes in sterile, comminuted beef stored at 10°C for 20 days. [4] Similarly, Simpson et al., 1995, demonstrated the anti-botulinal effects of salt and pH in minimally processed sous vide spaghetti and meat sauce on proteolytic C. botulinum. [5]

It should be noted though that for foods containing meat, fats or oils it is notoriously difficult to ensure uniform acidity throughout the product. [1]

Antimicrobials and Competitive Microorganisms

Protective cultures of various strains of lactic acid bacteria have also been examined as a suitable alternative to chemical preservatives for cook chill foods with promising results. However, generally this technique has involved the addition of cultures after the cooking process is complete which would not be possible in sous vide processing due to the hermetically sealed packs.

Bolton, 1998, investigated the suitability of several strains of lactic acid bacteria for use in sous vide beef and other products. However, none survived the minimal sous vide cooking to subsequently prevent the

[1] Food Standards Agency UK. Vacuum Packing and Modified Atmosphere Packing of Food – Online Training Course. < http://vacuumpackingtraining.food.gov.uk/introduction/> Accessed 31/03/11.

[2] Dick, H.M. et al. (1992). Advisory Committee on the Microbiological Safety of Food (ACMSF). Report on Vacuum Packaging and Associated Processes. London: HMSO.

[3] Bolton, D.J. (1998). The Microbiological Safety and Quality of Foods Processed by the 'Sous Vide' System as a Method of Commercial Catering. Teagasc Agriculture and Food Development Authority. <http://www.teagasc.ie/research/reports/foodprocessing/4031/eopr-4031.pdf> Accessed 28/03/11.

[4] Zhu, M. et al. (2005). Control of Listeria monocytogenes Contamination in Ready-to-Eat Meat Products. *Comprehensive Reviews in Food Science and Food Safety*, 4, 34 – 42.

[5] Marth, E.H. (1998). Extended Shelf Life Refrigerated Foods: Microbiological Quality and Safety. *Food Technology*, Vol. 52, No. 2, February 1998, p57 – 62.

propagation of pathogens. [1] Further studies are required in this field to determine appropriate cultures, if any, to use in sous vide processing.

This highlights a key disadvantage of bio-preservation. In general they require a complex development process starting with the screening of potential 'candidates' for protective cultures and finishing with sensory evaluation and scaled up production. In addition there is the need for legislative approval for the use of lactic acid bacteria in some countries including Australia. [2]

Spices

Some studies suggest that spices have an inhibitory effect on the survival of C.botulinum. [2,3] However, as a separate organic ingredient spices may also provide a secondary source of botulinum spores to the product. In any case the use of spices would significantly affect the sensory qualities of the product. However, if effective, spices may be able to be utilised in 'stew in bag' sous vide products such as lamb shanks and osso bucco.

7.4.3 Factors That Can Not Be Controlled or Monitored

It should be considered that for the retail market the temperature abuse of the product after purchase will be an unknown factor. This may significantly affect the safety of the product for example when stored in the boot of a car on the way home in summer. There is also the issue of maintaining consistent temperatures in typical household refrigerators. Evans (1998) reported a consumer study of 252 households which indicated that higher temperatures than desirable are to be found in home refrigerators. [4] These risks may be mitigated simply by adjusting the shelf life accordingly to allow for a minimal product storage post retail purchase. This may also be an application for predictive microbiology along with real life tests to model 'worst case scenarios' and in order to scale the acceptable shelf life.

These risks could also be mitigated by consumer education and finishing procedures. However, it is not clear from the current regulations whether relying on finishing procedures as a CCP is acceptable in retail. In the UK ACMSF (1992) recommends against relying on such controls that are ultimately in the hand of the end consumer. [5]

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[1] Bolton, D.J. (1998). The Microbiological Safety and Quality of Foods Processed by the 'Sous Vide' System as a Method of Commercial Catering. Teagasc Agriculture and Food Development Authority. <http://www.teagasc.ie/research/reports/foodprocessing/4031/eopr-4031.pdf> Accessed 28/03/11.

[2] Rodgers, S. (2005). Food safety research underpinning food service systems – a review. *Food Service Technology*, 5, 67 – 76.

[3] Dick, H.M. et al. (1992). Advisory Committee on the Microbiological Safety of Food (ACMSF). Report on Vacuum Packaging and Associated Processes. London: HMSO.

[4] Vaudagna, S. et al. (2002). Sous vide cooked beef muscles: effects of low temperature–long time (LT–LT) treatments on their quality characteristics and storage stability. *International Journal of Food Science and Technology*, 37, 425 – 441.

[5] Dick, H.M. et al. (1992). Advisory Committee on the Microbiological Safety of Food (ACMSF). Report on Vacuum Packaging and Associated Processes. London: HMSO.

8. Product Developments and Potential Markets

8.1 Summary of the Current Australian Market

There is an existing market for sous vide meat products in Australia, primarily in the food service and commercial catering industries. Off the shelf sous vide meat products are not available at a retail level except for Creative Food Solutions' Emily's Kitchen range of curries, steaks and stewed dishes which have been sold on a small scale at Woolworths. Although, little information was available on the Emily's Kitchen brand at the time of this study.

Table 10 below summarises some of the key Australian sous vide meat producers.

Table 10: Summary of Selected Australian Sous Vide Producers

Company	Company Information	Sous Vide Products	Key Clients	Other Comments
Byropin Pty Ltd	Operations in Sydney. $8 million annual turnover. 20 staff.	Beef, lamb, pork and veal roasts, steaks and ribs and various sous vide chicken dishes.	Various hospitals, nursing and retirement Homes, Meals on Wheels, clubs and caterers throughout NSW.	Over 8 weeks shelf life suggested if stored at 3°C or below.
Prepared Foods Australia	Operations in Brisbane. 100 staff.	Beef short ribs, beef back ribs, roast beef and veal, Vienna steaks.	Hospital, aged care and commercial catering markets.	Distribution across Australia and oversees exports of frozen sous vide products.
Caterers Cooked Meats	Operations in Melbourne.	Sous vide beef and lamb products.	Hospitals, health care facilities and commercial catering markets including airlines, shipping and rail. Products distributed throughout Australia.	4 to 6 week shelf life on most products suggests a relatively heat intensive cooking process. Customers are also offered online access to data logger information to verify cooking and cooling controls on selected batches.
Ilonka Foods	Operations in Perth.	Beef, lamb, pork, and chicken roasts. Also curries, casseroles and stews.	Commercial catering for large functions.	
Creative Food Solutions	Operations in Sydney.	Plated beef, chicken, lamb and turkey dishes, Various marinated products and curries, roasts, sauces and soups.	Industrial and corporate caterers, healthcare, clubs, hotels and resorts, restaurants and cafes. Products distributed throughout Sydney and coastal and regional NSW.	Sous vide products are cooked for 12 to 14 hours. 5 weeks shelf life is proposed from the date of production provided 0°C to 4°C storage.

8.2 Consumer Perceptions

Creed (2001) conducted a market survey in the UK to understand how consumers perceive the acceptability of prepared meals, including sous vide, according to age group, social class and frequency of eating out.

The key findings of the report with regards to consumer perceptions of sous vide meals are as follows: [1]

- There was a significant increase in the perceived acceptability of sous vide meals for those in upper social class[2] as compared to the lower social class.
- In general, the acceptability of all types of prepared meals increased with higher social classes and with frequency of eating out. [3]
- There was a tendency for the over 65 age group to perceive any method other than conventional cooking as far less acceptable.
- A general misconception or confusion was noted across the board that contributed to poor consumer attitudes towards meals prepared by foodservice systems. Consumers associated ready meals more with processed components rather than the actual mixture of preparation, cooking and chilling methods that formed the actual foodservice practice.

8.3 Marketable Attributes of Sous Vide Meals

Through this study and a review of the available literature, a number of marketable positive attributes associated with sous vide processing have become apparent. These are as follows:

- Sous vide products are pre-cooked under defined parameters to achieve a known outcome i.e. the degree of doneness can be guaranteed for the consumer;
- Significantly increased tenderness as a result of sous vide processing compared to conventional cooking methods, especially for lower grade cuts of beef;
- The juiciness and general mouth feel of the product is maintained;
- The cooking method allows the addition of marinades and sauces to add variety and develop a range of different products;
- Sous vide meat products could be marketed as an intermediate product between raw meat and ready meals;
- Sous vide processing allows at the consumer end, the production of a high quality meal relatively quickly; and
- There is potential to capitalise on the nutritional benefits associated with sous vide processing as discussed in Section 4.2.2. Although further studies are required in order to quantify this.
- Vacuum sealing prior to cooking can provide assurance of containment and guarantee the exclusion of undesired food components. This would be beneficial in marketing products such as organic and

[1] Creed, P. (2001). The potential of foodservice systems for satisfying consumer needs. *Innovative Food Science and Emerging Technologies*, 2, 219 – 227.

[2] Upper social class in this study was comprised of people with professional occupations.

[3] Frequency of eating out ranged from twice a week and over to less than once a month.

kosher meals. Creed (2001) found that many of those who for ethical, environmental, medical or religious reasons need reassurance on the quality of prepared meals, would consider elimination of the risk of contamination as essential. [1]

In addition to these there are benefits to the manufacturer associated with the capture of yield losses through the cooking process in the vacuum sealed bags. The cooking juices are subsequently paid for by the consumer and may not be an attribute worth highlighting in marketing sous vide products. However, cooking juices are the main constituents of flavourful sauces and jus' to compliment roast products. Hence, there is an opportunity to market this as an add on product/benefit associated with sous vide.

8.4 Potential Opportunity Products

8.4.1 Cuts of Beef

Typical retail pricing for beef products are summarised in Table 11 below.

Table 11: Typical Beef Retail Pricing [2]

Product	Typical Retail Price ($/kg)
Premium Cuts	
Eye Fillet Whole	$34.99
Scotch Fillet Steak	$26.06
Porterhouse	$24.04
Sirloin Steak	$22.27
Rib Eye Roast	$22.00
T-bone	$20.50
Mid Range Cuts	
Rump Rolled Roast	$18.75
Rump Steak	$18.97
Sandwich Steak/Sizzle Steak	$14.78
Eye Round Roast	$14.00
Low End Cuts	
Diced beef (casserole)	$13.28
Blade Steaks	$12.78
Topside Roast	$11.22
Beef Osso Bucco	$11.00
Blade Roast	$10.57
Chuck Steak	$10.27
Gravy Steak	$8.76

[1] Creed, P. (2001). The potential of foodservice systems for satisfying consumer needs. *Innovative Food Science and Emerging Technologies*, 2, 219 – 227.

[2] Pricing data obtained from Coles and Woolworths online shopping (www.coles.com.au and www.homeshop.com.au) and also in store prices at Coles Castle Towers Store. Pricing data obtained on 13/14/11 and 16/04/11.

Product	Typical Retail Price ($/kg)
Corned Silverside	$6.96
Market Value/Smartbuy Economy Brand	
Rump Steak	$12.00
Porterhouse Steak	$15.00
Scotch Fillet Steak	$15.99

The most significant marketable attribute of sous vide processing that has been identified through this study is the increased tenderness and sensory qualities as compared to conventional cooking methods particularly for the tougher lower grade cuts of beef. Considering this and the relative pricing between the various cuts of beef there is potential for sous vide processing in the low end cuts of beef and in the Market Value and Smartbuy Economy brand products. These are illustrated in Figure 9 below.

Figure 9: Typical Beef Product Breakdown and Sous Vide Opportunities

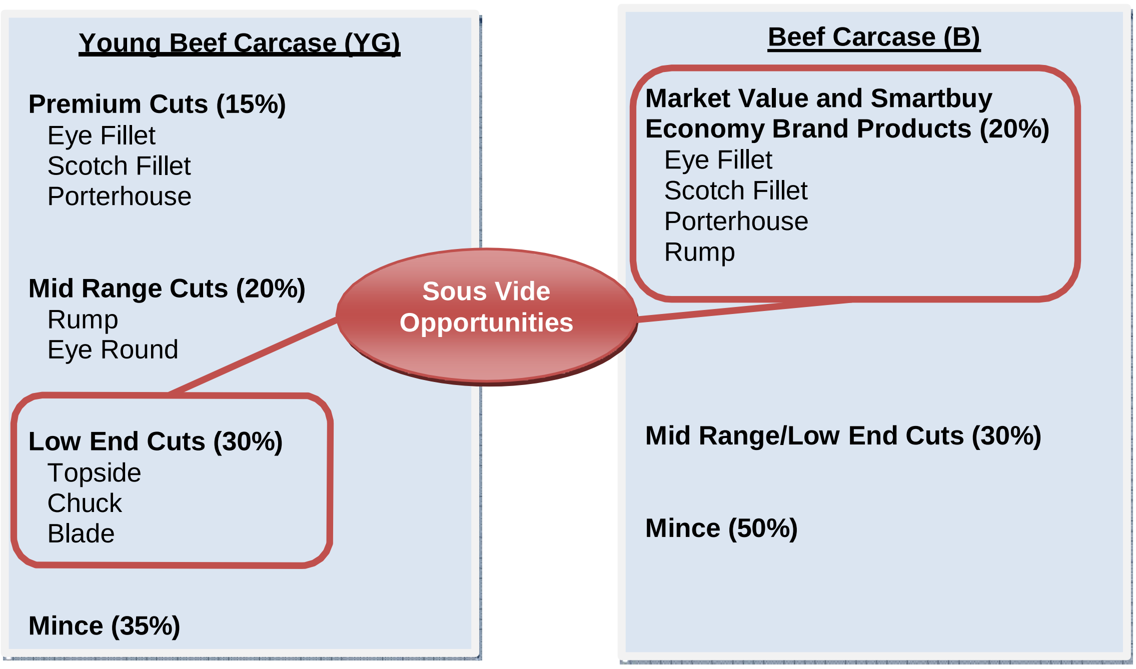

Table 12 outlines the typical costs at retail level of sous vide beef products based on the opportunity cuts identified in Figure 9. In general, the low end cuts are shifted into a price range of $10.00-14.50/kg, and the Market Value and Smartbuy Economy brand products are shifted into a price range of $13.20-17.20/kg.

The relative sous vide retail price column in Table 12 does not include an additional premium for the quality added to the product as a result of sous vide processing. Considering this opportunity there is significant potential for added revenue in sous vide beef products. For example, in Table 12, the added cost of sous vide processing Market Value/Smartbuy Economy brand Scotch Fillet steak brings its relative retail price to $17.22/kg compared to $15.99/kg for the fresh product. The corresponding or competing product in this case would be fresh premium Scotch Fillet priced at $26.06/kg. There is a price gap of $8.84/kg between the two products which could be narrowed by adding a premium to the sous vide product.

Table 12: Typical Retail Prices of Sous Vide Opportunity Products[1]

Product	Typical Retail Price ($/kg)	Relative Sous Vide Retail Price ($/kg)	Competing Product	Potential Added Revenue ($/kg)
Low End Cuts				
Diced beef (casserole)	$13.28	$14.51	Mid range cuts averaging $16.63/kg	$2.13
Blade Steaks	$12.78	$14.01		$2.63
Topside Roast	$11.22	$12.45		$4.19
Beef Osso Bucco	$11.00	$12.23		$4.41
Blade Roast	$10.57	$11.79		$4.84
Chuck Steak	$10.27	$11.50		$5.14
Gravy Steak	$8.76	$9.98		$6.65
Market Value/Smartbuy Economy Brand				
Rump Steak	$12.00	$13.23	Premium Rump @ $18.97/kg	$5.74
Porterhouse Steak	$15.00	$16.23	Premium Porterhouse @ $24.04/kg	$7.81
Scotch Fillet Steak	$15.99	$17.22	Premium Scotch Fillet @ $26.06/kg	$8.84

There is always the potential that developing sous vide beef products could cannibalise the existing raw meat markets. For the opportunities identified in this study, this would affect the premium and mid-range cuts. On the other hand it may be a case of sous vide products competing in the overall protein market rather than just in the red meat market. Further consumer studies would be required in the product development stage to attempt to predict and quantify this effect.

8.4.2 Cuts of Lamb

In general the opportunities for producing sous vide lamb products are limited. Lamb is significantly more expensive compared to beef as evidenced in Table 13.

[1] Relative sous vide pricing costs calculated by adding $0.98/kg processing costs to the wholesale meat prices and applying a 25% margin at retail. The vacuum bag costs were excluded from the sous vide processing costs as it is assumed that packaging is a neutral cost for the purposes of this exercise. $0.98/kg sous vide processing costs were used based on the calculations outlined in Section 6.3 of this report.

Table 13: Typical Lamb Retail Pricing [1]

Product	Typical Retail Price ($/kg)
Lamb Shanks	$9.50
Lamb Leg Roast	$13.50
Lamb Rump Steaks	$24.49
Lamb Cutlets	$36.25

Lamb is typically a relatively tender meat and the industry has already invested significantly in projects aimed at improving this quality. It is not envisaged that cooking lamb by sous vide would significantly improve the sensory qualities of the product as compared to conventional cooking although it would improve the consistency of outcomes. Sous vide lamb products would provide a known outcome for the consumer with regards to the degree of doneness, but this may not be worth the additional costs on top of this already relatively expensive product offering. There are also no savings brand lamb products as there is with beef that would lend themselves to value added processing.

Even lamb shanks, a popular low grade cut that would lend itself to sous vide processing would have limited potential in the market. There are already numerous lamb shank ready meal products on the market produced by conventional cook-chill methods. The difference in the overall sensory quality between these and sous vide lamb shanks are not likely to be significant enough for sous vide lamb shank products to be differentiated in the market. There may however be potential for a niche market of sous vide boned out leg roasts and shoulder roasts.

8.4.3 Potential Range Products

A professional chef experienced in sous vide cooking and possibly an appropriately qualified food scientist should be consulted in the early stages of product development in order to define appropriate recipes. A review of the literature has indicated that the sous vide process is extremely sensitive to the time-temperature set-points and also the types of ingredients used. Certain ingredients react differently under sous vide conditions that would not normally be expected. For example, extra virgin olive oil can result in an off/metallic taste. [2] Table 14 provides an overview of potential product offerings and their marketable attributes.

[1] Pricing data obtained from Coles and Woolworths online shopping (www.coles.com.au and www.homeshop.com.au) and also in store prices at Coles Castle Towers Store. Pricing data obtained on 13/14/11 and 16/04/11.

[2] Baldwin, D. (2008). A Practical Guide to Sous Vide Cooking. <http://www.douglasbaldwin.com/sous-vide.html> Accessed 01/03/11.

Table 14: Key Attributes of Potential Products

Product	Key Unique and Marketable Attributes
Steaks	Known degree of doneness. Individual steaks could potentially be sold under relevant categories of doneness such as rare, medium, well done etc.
Roasts	As with steaks, the pre-determined degree of doneness can be a marketable attribute. There is also the potential to market the cooking juices as a basis for an accompanying sauce or gravy.
Marinated Products	The low temperature – long time cooking process allows the flavour of marinades to infuse into the meat tissue.
Heart Tick/Healthy Choice Products	Less seasoning is required compared to conventional cooking methods. Additional fats are not required for the cooking process to prevent adhesion to the cooking surface. These factors may allow the development of healthy choice and heart tick approved ready meals.
Organic, Kosher, Halal and meals with specific medical and dietary requirements.	Vacuum sealing of ingredients can provide a guarantee of containment which may be beneficial in marketing products such as totally organic products, kosher meals and other meals with specific medical and dietary requirements.
Delicatessen cold cuts	The current market offering of red meat cold cuts is relatively limited compared to that of pork or chicken. There may be potential for the development of a range of sous vide processed cold cuts, provided that appropriate hurdles are in place to satisfy food safety requirements. The infusion of flavours and marinades during the pasteurisation process may allow the development of a range of red meat cold cuts.

8.5 Other Marketing Issues to Consider

8.5.1 Presentation and Packaging

Consideration of presentation and packaging will be paramount to the success of sous vide meat products. In the first instance the key question to address is how the producers and retailers would want the consumers to view the product. The packaging should then be designed accordingly. An example in the current market is the Market Value/Smartbuy Economy brand fresh products. These are positioned as budget products and the packaging emphasises this typically with a minimal 'no frills' labelling design and white plastic packaging to emphasise the cost savings. Conversely, sous vide products may be marketed as premium quality products due to the enhanced sensory qualities.

Another issue to consider with the packaging design of sous vide products is whether to hide the actual product itself. The end result of sous vide processing, depending on the pasteurisation process, is a product that resembles rare meat or poached meat. Either way the product is not particularly aesthetically appealing until the finishing procedure is undertaken unless the product is disguised by a sauce in the bag. Consideration must be given as to whether consumers will be deterred from purchasing sous vide products as a result of their general look.

8.5.2 Finishing Procedures

The fact that sous vide products require specific finishing procedures means that the marketable attributes of tenderness and enhanced sensory quality are ultimately reliant on the skill and knowledge of the end consumer. There is a risk associated with this that will need to be managed if sous vide products are introduced in the retail market. If a consumer trialled a sous vide product and overcooked it, the end result may be a tough and dry product which will not be subsequently purchased again. Consumer education relating to finishing procedures will need to be a key component of a marketing campaign for retail sous vide products.

8.5.3 Potential of Industrial Foodservice Market

There is an existing market for sous vide meat products in the foodservice and commercial catering industries in Australia. A further study into the size of this market and potential opportunities for growth would be beneficial. There may be considerable additional opportunities in industrial foodservice sectors such as healthcare, airlines, freight and shipping.

9. Competing and Complimentary Processes and Technologies

There is the potential that sous vide red meat products would compete with the existing market of premium raw cuts. There is also a small presence in the retail market of cook-chill ready meals and shelf stable meat products.

None of these products however provide both a guaranteed outcome in terms of the degree of doneness and the sensory quality of the finished product. This gives sous vide meat products a very unique selling point in the market in addition to being price competitive with premium and mid-range cuts of beef. Table 15 below summarises some of the key advantages and disadvantages of competing products with respect to sous vide products.

Table 15: Competing Products

Category	**Product**	**Pros**	**Cons**
Fresh	Premium cuts of beef	Association with high sensory qualities.	Expensive products. The outcome and product quality is not guaranteed for the consumer.
Fresh	Pre-prepped marinades and roasts.	Market familiarity. These are raw products so food safety issues are not a major concern as with sous vide.	The outcome and product quality is not guaranteed for the consumer.
Cook-Chill	Ready meals.	Variety of products available.	Heat intensive pasteurisation processes generally resulting in well done, tough products.
Shelf Stable	Fully sterilised cook-in-bag meat products.	Long shelf life and food safety assurance.	These products always contain a sauce to add moisture and mask the dry, overcooked product that results from a fully sterilising process.

10. Further Studies

This report has defined the key elements of the sous vide process in terms of potential products, required processing equipment, operating constraints and safety issues. Pricing estimates have also been provided in order to gauge the likely capital costs and ongoing operational costs associated with commercial scale production at various throughputs.

In examining the issues surrounding the potential of sous vide processing to provide value added red meat products on both a commercial food service and retail level, we have identified a number of areas that require further studies and investigations. These are summarised as potential flow on projects. Table 16 below illustrates the defined aspects and knowledge gaps with regards to sous vide processing and its applications to the red meat industry.

Table 16: Current State of Knowledge

	Defined	Partially Defined	Further Studies
Product Development	• Marginal processing cost estimates. • Equipment specifications.	• Optimum pasteurisation set-points. • Potential cuts of beef. • Guidelines for sous vide producers.	• Ingredients and recipes. • Specific cuts of beef. • Portion sizes. • Potential of nutritional meals. • Potential organic, kosher etc meals.
Food Safety	• Food Safety Regulations	• Equivalent time-temperature lethality profiles. • Potential hurdles identified.	• Lethality of pasteurisation processes. • Effect of hurdles on safety/quality. • Cold chain thermal stresses. • End of line sterilisation technologies.
Marketing & Consumer Studies	• Marketable attributes of sous vide products	• State of the current Australian sous vide market. • Potential cannibalisation of fresh meat products.	• Packaging and marketing strategy at a retail level. • Cannibalisation effects on fresh meat products. • Market acceptability of sous vide products. • Finishing procedure education and clarity of instructions • Opportunities for growth in the industrial foodservice market

10.1 Product Development Projects

Project – Definition of recipes for sous vide products

Issue – A product development study must be undertaken to identify and define the cuts of meat that have significant value add potential if processed by sous vide. Products would need to be considered with respect to variables such as portion size, recipe and finishing for service. The time and temperature set-points for the pasteurisation process will need to be defined and will depend on regulatory requirements and the technical aspects of the recipe. As such a chef experienced in sous vide cooking and possibly an appropriately qualified food scientist should be utilised in this project.

Outcome – Definition of a small range of products in terms of the ingredients, recipe, preparation methods and cooking procedures.

Project – Nutritional benefits of sous vide processing

Issue – The potential nutritional benefits of sous vide processing with respect to low salinity and low fat additions needs to be investigated in order to determine whether there is potential to develop healthy choice and heart tick approved ready meals. If this is the case then this could open up an additional market for sous vide products.

Outcome – Define through further research and product trials the potential nutritional qualities of sous vide products. Determine the feasibility of obtaining heart tick approval or the like for sous vide products.

Project – Sous Vide Processors Service Pack

Issue – Potential sous vide producers require education on the issues surrounding product development, processing, operations and food safety.

Outcome – MLA to develop a service pack for potential sous vide processors. The service pack should highlight the pertinent issues and risk management strategies relating to the safety issues and also provide guidance on recipes and product development.

10.2 Food Safety Projects

Project – Lethality of pasteurisation process

Issue – Following on from the definition of product recipes, the lethality of the pasteurisation process must be examined through microbiological testing.

Outcome – Quantified lethality of the pasteurisation process for each product for input into the assessment of shelf life limits.

Project – Potential use of hurdles in sous vide processing

Issue – Hurdles have been suggested as a way of mitigating safety risks and attaining compliance with current regulations. For sous vide processing the effects of hurdles and combinations of various controlling factors on microbial stability and sensory quality needs to be determined. Of particular importance is the effect of hurdles on product sensory quality which has not been addressed in the literature. This study could also address the issue of freezing to ensure food safety and the effect on the tenderness of the end product.

Outcome – Define through further research and product trials the effectiveness of various hurdles in controlling the propagation of pathogens and the effects of those hurdles on the sensory qualities of the end product.

Project – Cold chain thermal stress analysis

Issue –There is potential for the use of microbiological modelling and real life testing of thermal stress scenarios that can be expected in the retail market.

Outcome – Quantified expected cold chain thermal stress scenarios for input into the assessment of product shelf life limits.

Project – End of line sterilisation technologies

Issue –There may be potential for the application of end of line sterilisation technologies such as HPP and irradiation to minimise the safety risks associated with sous vide processing.

Outcome – Define the microbial stability attained from potential sterilisation technologies and the effects on the sensory qualities of sous vide products.

10.3 Marketing and Consumer Studies

Project – Commercial foodservice market studies

Issue – Further studies are required in order to determine the size and opportunities for growth in the existing sous vide market in the commercial foodservice industry.

Outcome – Define business opportunities for sous vide products in the commercial foodservice market.

Project – Retail product direction

Issue – The key question to address is how the sous vide producers and retailers would want the consumers to view the products. This will determine how the products are placed within the red meat market.

Outcome – Determine a direction and strategy for input into the product packaging design and advertising.

Project – Retail consumer trials and behaviour studies

Issue – Consumer attitudes with regards to sous vide products are currently an unknown. Product trials will need to be undertaken in order to gauge the acceptability of sous vide products in the retail market. A consumer behaviour study would also be beneficial in order to predict and quantify the potential of sous vide products to cannibalise the existing red meat market.

Outcome – Define the consumer perceptions of sous vide products for input into the assessment of adding an additional premium for product quality at retail. Define the potential of sous vide products to cannibalise the existing red meat market.

Project – Finishing procedure education and trials

Issue – Consumer education strategies will need to be developed and consumer trials undertaken to assess the clarity and effectiveness of the finishing instructions for sous vide products in ensuring that the promoted product qualities are achieved in the finished product.

Outcome – Qualitative verification of the clarity and effectiveness of the finishing procedures designed for each product.

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Appendix A

Sous Vide Equipment Specifications and Supplier Details

Manufacturer	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]		
Capital cost (equipment purchase)	$7,650 (Budget estimate from FPE)	$14,950 (Budget estimate from FPE)	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Vacuum pump capacity	63m3			63 M3 BUSCH Vacuum pump	100 M3 BUSCH Vacuum pump	300 M3 BUSCH Vacuum pump		20 m3/h Soft air device	40 m3/h Freestanding	
Floor space required	730 x 850 mm									
Country of origin	Manufactured in the Netherlands. Australian sales through Food Processing Equipment (FPE).	Manufactured in the Netherlands. Australian sales through Food Processing Equipment (FPE).	[illegible]				[illegible]	[illegible]	[illegible]	
Local support and supply	FPE's Head Office and Australian distribution warehouse is in Pooraka, South Australia. All spares stored in the SA warehouse with overnight delivery across Australia. There are 3 nationwide service technicians and 1 based in the SA workshop.	FPE's Head Office and Australian distribution warehouse is in Pooraka, South Australia. All spares stored in the SA warehouse with overnight delivery across Australia. There are 3 nationwide service technicians and 1 based in the SA workshop.	[illegible] based in the SA workshop.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Michael Moreson (Larger production units specialist) michaelm@fpe.net.au Mob. 0412667284 William Lillecrapp (Business Development Manager - FPE) [illegible]	Michael Moreson (Larger production units specialist) michaelm@fpe.net.au Mob. 0412667284 William Lillecrapp (Business Development Manager - FPE) Mob: 0438 716 267 Email: williaml@fpe.net.au	Michael Moreson (Larger production units specialist) michaelm@fpe.net.au Mob. 0412667284 William Lillecrapp (Business Development Manager - FPE) Mob: 0438 716 267 Email: williaml@fpe.net.au	[illegible]	[illegible]	[illegible]	[illegible] NSW 2111 elenn.robertson@aneelooo.com.au	[illegible] elenn.robertson@aneelooo.com.au	[illegible] NSW 2111 [illegible] elenn.robertson@aneelooo.com.au	

	Equipment Type	Combination Oven	Combination Oven	Combination Oven	Combination Oven	Blast Chiller/Freezer	Blast Chiller/Freezer
	Manufacturer	Rational	Rational	Angelo Po	Angelo Po	Angelo Po	Angelo Po
	Model	CombiMaster 202E	CombiMaster 102E	Combistar FX202E3	Combistar FX101E3	ISR202R Blast Chiller / Freezer	IS101SR Blast Chiller / Freezer
	Capital cost (equipment purchase)	$44,411 + GST (hospitality warehouse.com.au) $58,500 + GST (Australian distributer - Comcater)	$23,981 + GST (commercialfood equipment.com.au) $30,000 + GST (Australian distributer - Comcater)	$41,400 + GST (sydneycommercialkitchens.com.au) RRP $56,560 + GST (Quote from Angelo Po)	$20,130 + GST (sydneycommercialkitchens.com.au) RRP $27,500 + GST (Quote from Angelo Po)	RRP $60,045 + GST (Quote from Angelo Po)	RRP $17,200 + GST (Quote from Angelo Po)
	Production capacity	Holds 20 x GN 2/1 containers (530 x 650 x 65mm) Batch size is approx 450 meals/portions	Holds 10 x GN 2/1 containers (530 x 650 x 65mm) Batch size is approx 225 meals/portions	Cooking chamber 890 x 825 x 1460 mm Holds 40 x GN 1/1 containers (510 x 310 x 65mm internal container dimensions) Batch size is approx 450 meals/portions	Cooking chamber 645 x 650 x 755 mm Holds 10 x GN 1/1 containers (510 x 310 x 65mm internal dimensions) Batch size is approx 120 meals/portions	Sized to match the Angelo Po Combistar FX202E3 oven. 825x1005x1850mm trolley to load product and wheel into the chiller.	Sized to match the Angelo Po Combistar FX101E3 oven.
	Temperature/ process control	Vario-steaming from 30°C - 99°C Combination cooking from 30°C - 300°C Accuracy of temperature control is +/- 3°C	Vario-steaming from 30°C - 99°C Combination cooking from 30°C - 300°C Accuracy of temperature control is +/- 3°C	Convection cooking from 30°C - 250°C % steam from 0 to 90 Steam from 30°C - 125°C Accuracy of temperature control is +/- 3°C	Convection cooking from 30°C - 250°C % steam from 0 to 90 Steam from 30°C - 125°C Accuracy of temperature control is +/- 3°C	210 kg of product from +90° C to +3°C in 90 minutes and 144 kg of product from +90°C to- 18°C in 240 minutes. Tropicalized at 43°C (climate class T or 6 ISO441).	42 kg of product from +90° C to +3°C in 90 minutes and 25 kg of product from +90°C to -18°C in 240 minutes. Tropicalized at 43°C (climate class T or 6 ISO441).
	Floor space required	1084 x 996 mm	1069 x 971 mm	1193 x 1074 mm	920 x 874 mm	1400 x 1250 mm	800 x 830 mm
	Mass	326 kg	175.5 kg	449 kg	198 kg	360 kg	195
	No. operators	1	1	1	1	1	1
Utilities/services	Power	66.5 kW, 415V 3ph connection	40.5 kW, 415V 3ph connection	55.5 kW, 400V 3 ph connection	17.3 kW, 400V 3 ph connection	1.2 kW, 400V 3 ph connection	0.28 kW, 400V 3 ph connection
	Gas			55 kW for gas powered version	NA	NA	NA
	Process water	3/4 in intake at 1.5 - 1.6 bar pressure	3/4 in intake at 1.5 - 1.6 bar pressure	3/4 in intake at 2 bar pressure	3/4 in intake at 2 bar pressure	NA	NA
	Steam	NA	NA	NA	NA	NA	NA
	Hot water	NA	NA	NA	NA	NA	NA
	Chilled water	NA	NA	NA	NA	NA	NA
	Compressed Air	NA	NA	NA	NA	NA	NA
	Country of origin	Manufactured in Germany and distributed throughout Australia by CCE International (Comcater) 10-12 weeks lead time if not in stock in Australia.	Manufactured in Germany and distributed throughout Australia by CCE International (Comcater) 10-12 weeks lead time if not in stock in Australia.	Manufactured in Italy and distributed throughout Australia by Galleria Rosso Pty Ltd	Manufactured in Italy and distributed throughout Australia by Galleria Rosso Pty Ltd	Manufactured in Italy and distributed throughout Australia by Galleria Rosso Pty Ltd	Manufactured in Italy and distributed throughout Australia by Galleria Rosso Pty Ltd
	Local support and supply	Spare parts stock holdings in Melbourne, Sydney, Brisbane and Perth. 24/7 local technical support provided by 5 service technicians across Australia.	Spare parts stock holdings in Melbourne, Sydney, Brisbane and Perth. 24/7 local technical support provided by 5 service technicians across Australia.	National spare part warehouse in Victoria. 24/7 local support service from a range of providers.	National spare part warehouse in Victoria. 24/7 local support service from a range of providers.	National spare part warehouse in Victoria. 24/7 local support service from a range of providers.	National spare part warehouse in Victoria. 24/7 local support service from a range of providers.
	Contact	Comcater.com.au NSW/ACT Sales Showroom & Demonstration Kitchen Unit 20/4 Avenue Of The Americas, Newington, NSW, 2127 Ph: 02 9748 3000 Nick Mob. 0417556248	Comcater.com.au NSW/ACT Sales Showroom & Demonstration Kitchen Unit 20/4 Avenue Of The Americas, Newington, NSW, 2127 Ph: 02 9748 3000 Nick Mob. 0417556248	Glenn Robertson Director- Angelo Po & SAGI Australia Unit 24/43-51 College St, Gladesville NSW 2111 Ph. 02 9879 7255 Mob. 0425 766 610 Email. glenn.robertson@angelopo.com.au	Glenn Robertson Director- Angelo Po & SAGI Australia Unit 24/43-51 College St, Gladesville NSW 2111 Ph. 02 9879 7255 Mob. 0425 766 610 Email. glenn.robertson@angelopo.com.au	Glenn Robertson Director- Angelo Po & SAGI Australia Unit 24/43-51 College St, Gladesville NSW 2111 Ph. 02 9879 7255 Mob. 0425 766 610 Email. glenn.robertson@angelopo.com.au	Glenn Robertson Director- Angelo Po & SAGI Australia Unit 24/43-51 College St, Gladesville NSW 2111 Ph. 02 9879 7255 Mob. 0425 766 610 Email. glenn.robertson@angelopo.com.au

Appendix B

Production Line Pricing Calculations

Marginal Costing for 1800 Portions/Day Throughput Production Line Combi Ovens and Blast Chillers				
Item	**Qty**	**Description**	**Cost**	**Comments**
CAPEX				
Vacuum Packaging				
Vacuum packing machine	1	Vacutec EPX 70	$11,500	
Working bench	1	1800 x 600 x 900 mm high SS bench with shelf underneath	$1,575	
Cool room	1	3 x 5 x 2.4 m high insulated panel cool room with cooling equipment	$23,600	
Pasteurisation				
Combi oven	4	Angelo Po Combistar FX202E3	$226,240	
Product racks	6	SS racks that can be loaded with product for the ovens and chiller	$6,000	
Chilling				
Blast chiller	1	Angelo Po ISR202R	$60,045	
		Total Capital Equipment Cost	**$328,960**	
		Commercial Hire Purchase (CHP) Monthly Repayment	**$6,528**	Estimate provided through Esanda online repayments calculater. Input data: 5yr term, 8.5% interest rate and 5% estimated final value of goods at the end of the contract.
OPEX (PER DAY)				
Utilities - Power (key items)				
Vacuum packing		3.3kW packer operated for 4 hours @ $0.10/kWh	$1.32	
Vacuum packing room chiller		15kW chiller operated for 24 hours @ $0.10/kWh	$36	
Combi ovens		4 x 55.5kW ovens operated for 24 hours @ $0.10/kWh	$266.40	Combi ovens assumed to be running at half capacity due to the low temperature cooking process.
Blast chiller		1.2kW chiller operated for 8 hours @ $0.10/kWh	$0.96	
Utilities - Water				
Process and cleaning water		Estimate 400L per day @ $2/kL	$0.80	
Labour				
Operator costs		3 operators working 8 hour shifts @ $50/hr	$1,200	Hourly rates estimated to include overheads such as payroll,
Maintenance costs		Maintenance technician working 1hr per day @ $60/hr	$60	admin and insurances.
		Total Operating Costs Per Day	**$1,565**	
MARGINAL COSTING CALCULATIONS				
		Total Annual CAPEX and OPEX Costs	**$485,360.80**	5 days/week, 260 days/year operations assumed
		Total Annual Packs Produced	**468000**	
		Total Annual kg Product Produced	**234000**	
		Cost of Sous Vide Process Per Pack	**$1.04**	
		Cost of Sous Vide Process Per kg Product	**$2.07**	

Marginal Costing for 1800 Portions/Day Throughput Production Line Using Cook-Chill Tanks

Item	Qty	Description	Cost	Comments
CAPEX				
Vacuum Packaging				
Vacuum packing machine	1	Vacutec EPX 70	$11,500	
Working bench	1	1800 x 600 x 900 mm high SS bench with shelf underneath	$1,575	
Cool room	1	3 x 5 x 2.4 m high insulated panel cool room with cooling equipment	$23,600	
Pasteurisation and Chilling				
Cook-chill tanks	2	CKCT-10 Automatic Cook Chill Tank	$124,925	Unit comes with 1 basket/rack set and 1 trolley
Additional product racks	3	SS Basket/rack assembly for loading of product into/out of the tanks	$23,790	
Additional Trolleys	3	SS trolleys for transportation of product basket/racks	$8,445	
Hoist and monorail	1	For loading and unloading the product baskets into/out of the tanks	$41,603	
Steam generation system				
Steam generator	1	48kW steam generator	$26,300	
High pressure 25mm SS piping	1	50m piping @ $65/m	$3,250	
Hot water pipe insulation	1	50m piping insulation @ $58/m	$2,900	
Valves and other instruments	5	5 ball valves @ $160 each	$800	
Chilled water/glycol system				
Chilled water tank	1	Insulated chilled water storage tank	$2,000	
Pump	2	1 x circulation pump and 1 x process pump. 5L/s, 10m head, 1.1kW	$6,700	
Chiller	1	12kW process cooling unit	$13,500	
25mm SS piping	1	50m piping @ $80/m	$4,000	
Chilled water pipe insulation	1	50m piping insulation @ $114/m	$5,700	
Valves and other instruments	5	5 ball valves @ $160 each	$800	
		Total Capital Equipment Cost	**$301,388**	
		Commercial Hire Purchase (CHP) Monthly Repayment	**$5,981**	Estimate provided through Esanda online repayments calculater. Input data: 5yr term, 8.5% interest rate and 5% estimated final value of goods at the end of the contract.
OPEX (PER DAY)				
Utilities - Power (key items)				
Vacuum packing		3.3kW packer operated for 4 hours @ $0.10/kWh	$1.32	
Vacuum packing room chiller		15kW chiller operated for 24 hours @ $0.10/kWh	$36	
Cook chill tanks		2 x 5.8kW cook tanks operated for 24 hours @ $0.10/kWh	$27.80	
Chilled water system		12kW process cooling unit operated for 8 hours @ $0.10/kWh	$9.60	
Compressor		Approx 5 kW compressor operated for 8 hours @ $0.10/kWh	$4.00	
Utilities - Water				
Process water - cooking		2 x 1000L cooking batches @ $2/kL	$2.00	
Process water - cooling		2 x 1000L cooling batches @ $2/kL	$2.00	
Cleaning water		Estimate 400L/day	$0.80	
Utilities - Gas				
Boiler		48kW steam generator operated for 24 hours @ $0.018/MJ	$74.65	
Labour				
Operator costs		2 operators working 8 hour shifts @ $50/hr	$800	Hourly rates estimated to include overheads such as payroll,
Maintenance costs		Maintenance technician working 1hr per day @ $60/hr	$60	admin and insurances.
		Total Operating Costs Per Day	**$1,018**	
MARGINAL COSTING CALCULATIONS				
		Total Annual CAPEX and OPEX Costs	**$336,496.20**	5 days/week, 260 days/year operations assumed
		Total Annual Packs Produced	**468000**	
		Total Annual kg Product Produced	**234000**	
		Cost of Sous Vide Process Per Pack	**$0.72**	
		Cost of Sous Vide Process Per kg Product	**$1.44**	

Marginal Costing for 5400 Portions/Day Throughput Production Line Using Cook and Chill Tanks

Item	Qty	Description	Cost	Comments
CAPEX				
Vacuum Packaging				
Vacuum packing machine	1	Vacutec EPX 165	$31,500	
Working bench	2	1800 x 600 x 900 mm high SS bench with shelf underneath	$3,150	
Cool room	1	3 x 5 x 2.4 m high insulated panel cool room with cooling equipment	$23,600	
Pasteurisation and Chilling				
Cook-chill tanks	4	DC Norris CT-20 Cook/Chill Tank	$416,640	
Product racks	5	SS Basket/rack assembly for loading of product into/out of the tanks	$59,325	
Product rack trolleys	3	SS trolleys for transportation of product basket/racks	$6,675	
Basket lift-out frame	1	Additional frame for batch on standby for loading	$5,050	
Hoist and monorail	1	For loading and unloading the product baskets into/out of the tanks	$61,835	
Steam generation system				
Boiler	1	860kPa 100kW boiler	$43,000	
High pressure 25mm SS piping	1	50m piping @ $65/m	$3,250	
Hot water pipe insulation	1	50m piping insulation @ $58/m	$2,900	
Valves and other instruments	5	5 ball valves @ $160 each	$800	
Chilled water/glycol system				
Chilled water tank	1	Insulated chilled water storage tank	$2,000	
Pump	2	1 x circulation pump and 1 x process pump. 5L/s, 10m head, 1.1kW	$6,700	
Chiller	1	12kW process cooling unit	$13,500	
25mm SS piping	1	50m piping @ $80/m	$4,000	
Chilled water pipe insulation	1	50m piping insulation @ $114/m	$5,700	
Valves and other instruments	5	5 ball valves @ $160 each	$800	
		Total Capital Equipment Cost	**$690,425**	
		Commercial Hire Purchase (CHP) Monthly Repayment	**$13,701**	Estimate provided through Esanda online repayments calculater. Input data: 5yr term, 8.5% interest rate and 5% estimated final value of goods at the end of the contract.
OPEX (PER DAY)				
Utilities - Power (key items)				
Vacuum packing		4.4kW packer operated for 6 hours @ $0.10/kWh	$2.64	
Vacuum packing room chiller		15kW chiller operated for 24 hours @ $0.10/kWh	$36	
Cook tanks		3 x 8.4kW cook tanks operated for 24 hours @ $0.10/kWh	$60.48	
Chill tank		1 x 8.4kW chill tank operated for 6 hours @ $0.10/kWh	$5.04	
Chilled water system		12kW process cooling unit operated for 8 hours @ $0.10/kWh	$9.60	
Utilities - Water				
Process water - cooking		3 x 1500L cooking batches @ $2/kL	$9.00	
Process water - cooling		1 x 1500L cooling batch @ $2/kL	$3.00	
Cleaning water		Estimate 1000L/day @ $2/kL	$1.00	
Utilities - Gas				
Boiler		100kW boiler operated for 24 hours @ $0.018/MJ	$155.52	
Labour				
Operator costs		4 operators working 8 hour shifts @ $50/hr	$1,600	Hourly rates estimated to include overheads such as payroll, admin and insurances.
Maintenance costs		Maintenance technician working 2hr per day @ $60/hr	$120	
		Total Operating Costs Per Day	**$2,002**	
MARGINAL COSTING CALCULATIONS				
		Total Annual CAPEX and OPEX Costs	**$685,009.60**	5 days/week, 260 days/year operations assumed
		Total Annual Packs Produced	**1404000**	
		Total Annual kg Product Produced	**702000**	
		Cost of Sous Vide Process Per Pack	**$0.49**	
		Cost of Sous Vide Process Per kg Product	**$0.98**	