Horticulture Innovation Australia

Final Report

Development of chestnut bin scale controlled atmosphere system (CALM)

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Sydney Postharvest Laboratory

Project Number: CH02003

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Purpose of the report:

This report communicates the research undertaken as part of this project and describes the technology developed. It also describes improved postharvest handling procedures that will maximize the benefits of this technology to the Australian chestnut industry.

Date of Report: 30 April 2007

Acknowledgments

Thanks to the Chestnut Growers of Australia Ltd for funding this project. Together with practical support and advice from many growers, especially Joe Rinaudo, High Grove, Stanley, Brian and Jane Casey, Cheznuts, Eurobin Victoria and Nightingale's, Wandiligong. Special thanks are due to Dr Jenny Jobling at Applied Horticultural Research for her professional and scientific advice and contributions to the research.

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Media Summary

Chestnuts are harvested over a short period of a few weeks, but are in demand by consumers over the cooler months of the year. Currently, external mould is major problem, often limiting storage of high quality nuts to less than two months. A new technology has been developed for the Australian chestnut industry that enables chestnuts to be stored for over nine months without significant external mould. Control of mould is based not on pesticides, but rather on using the natural respiration of the chestnuts to raise the carbon dioxide level around them to high levels (> 15%) and reducing oxygen levels to below 5%. This is achieved with technology developed in this project which combines special airtight packaging around the bins of chestnuts and an inexpensive oxygen/carbon dioxide controller that runs on 12V DC. This system is known as CALM (Controlled Oxygen Longlife Module) and one unit is capable of controlling the oxygen/carbon dioxide levels of up to 1.6 tonnes of chestnuts stored in four half tonne bins. The current CALM version is Version 7. Multiple CALM units can be used within a coolroom and the ability to remove a bin at time from a stack enables maximum flexibility in marketing. This flexibility is not possible with a controlled atmosphere room.

The system integrates well with normal chestnut handling and cool storage and provides safe pesticide free chestnuts. Suggested modifications to current postharvest handling that will help optimise chestnut quality, include correct harvesting, sanitizing, slight weight (water) loss of 1 to 3% before storage using the CALM system at about -2°C. This system will enable growers to greatly improve the quality of their chestnuts, enabling good prices to be obtained throughout the cooler months of the year. Indeed with the CALM system and recommended handling quality chestnuts can be stored for over 9 months compared with the current 2-3 months. Further work is required to continue fine-tuning the system to integrate in the most practical and cost effective way in the Australian chestnut industry. This system has the potential to be expanded to benefit a considerable number of horticultural crops (ie other nuts and berry fruits) and it is recommended that research be done to enable this. CALM units developed for other crops besides chestnuts, will be given different series names to signify this i.e. CALM Sv3 for the Strawberry version.

The chestnut production in Australia according to the most recent statistics was worth $6.8 million, with almost of the nuts consumed domestically. The losses during storage without the advanced disease control achieved by CALM systems would be at least 10 – 15%, or $0.5 to 0.8 million dollars. The use of the CALM system (together with other suggested procedure changes) would be expected to reduce these losses by at least 2/3rd, giving a total potential benefit to the Australian industry of $0.3 to 0.6 million dollars. The cost of a CALM system is about $1,000, with increased returns to growers from each CALM system already established as worth between $1,000 to $5,000 per annum.

Technical Summary

The problem being addressed is the short storage life of harvested chestnuts (*Castanea sativa* Mill.). This short storage life is due to external rots, general senescence and internal rots. Previous research has indicated that external rots and senescence can be reduced by fungicides, controlled atmosphere and a range of other treatments including underwater storage. However, none of these procedures give complete control and are difficult to integrate into the handling and marketing of chestnuts within the Australian context. Preliminary testing within a previous HAL project (CH01001) had indicated that controlled modified atmosphere had considerable potential, although many technical problems needed to be solved to achieve this in a practical way for the Australian chestnut industry.

The initial concept was for a simple stick-on atmosphere patch (SOAP) that would control the internal atmosphere within a sealed bag to desired oxygen and carbon dioxide levels. However, as the system developed with grower input each controller ended up maintaining the required atmosphere for up to $10,000 of chestnuts. It was essential that each controller operated in very robust and reliable fashion, otherwise failure of a $200 controller could result in the loss of $10,000 chestnuts. This requirement meant a more complex and robust design, with a CALM (Controlled Atmosphere LongLife Module) unit which would be reused over several years. A wide range of critical components ie oxygen sensors, pumps were tested over several years, both in the laboratory and on grower's properties in order to select the most reliable system operating under actual conditions experienced in chestnut cool stores. A wide range of sealing systems and interfaces of the CALM controller were also assessed before coming up with a workable system. The electronic design needed also to be optimized for reliable operation under the damp and moist conditions in a chestnut coolroom, the layout of components on the printed circuit board (PCB) and water-resistant coating of the PCB was found to be very important.

Finally, the best oxygen and carbon dioxide levels were determined in the storage atmosphere. If the oxygen in the atmosphere was too low, then the nuts could become anaerobic and develop off-flavours and an alcoholic taint. If the oxygen level was too high (and therefore the carbon dioxide level too low), then the control of rots would be reduced. It was found that the best conditions were oxygen levels of 4% and carbon dioxide levels of about 16%, which ensured good control of external rots with a sufficient safety margin.

In combination with the CALM storage system, it is also strongly recommended that a fully optimized handling and storage system be used. This involves

- harvesting nuts carefully with minimum damage and moving quickly to the shed
- using a sanitizer or hot water/sanitizer to cleanup any infections
- holding the nuts for several days in open bins in cool storage to allow slight loss of weight or water of about 1 to 3%
- storage using the CALM system
- running the cool room at -2°C to ensure best storage conditions within the CALM system

Introduction

Chestnuts are harvested over a short period of a few weeks, from late March to early May, but in high demand particularly over all the cooler months of the year. Currently external mould is major problem limiting storage of nuts to less than two months.

In this project the issue to be investigated is the extended storage life of chestnuts that possible when using control atmosphere (CA) storage, especially high carbon dioxide CA. Previous smaller scale testing in project CH01001 had found that bin scale CA storage (controlled ventilation to keep CO_2 levels of about 16% and oxygen levels of about 5%) showed great promise - reducing external rots from 55 to 6% and internal rots from 10.7% to 0.5%. Also showing promise was room CA, with elevated carbon dioxide levels of about 25% and oxygen levels of about 12%, reducing external rot levels from 2.8 to 0.9%.

Previous research has used fungicides or sanitisers to control mould on chestnuts. Several postharvest disease control treatments where found to be effective, ranked in order of effectiveness, these are:

- Iodine at 30 ppm a.i. at 55ºC for 2 min[9] (registered for Aust. chestnuts).
- Carbendazim at 250 ppm a.i. for 1 min[3, 9] (not registered for Aust. chestnuts)
- Chlorine (sodium hypochlorite) at 100 -200 ppm a.i. and pH 7.5 for 1 min[1, 4, 6, 7, 10, 12] (approved for Aust. chestnuts).
- Peracetic acid at 100 ppm a.i. (Tsunami or Vortexx) for 1 min[1] (approved for Aust. chestnuts).

Other postharvest disease control measures that have been reported as effective, but not tested on Australian chestnuts are:
- Water curing which involves holding chestnuts under water at ambient temperatures (~15ºC) until fermentation starts (bubbles given off) in 3 to 9 days[1, 7, 10, 11]
- Heat treatment holding in water at 50-70ºC for 30 to 45 min[5, 6, 10, 11]

Previous research has also used controlled atmosphere to control chestnut mould. High carbon dioxide >10% and low oxygen <5% has been demonstrated to considerably extend storage life beyond that of cold storage in air [2, 6, 7, 8, 10]. However, with previously developed technology, this is only reliably achieved with controlled atmosphere rooms, rather than any system based on modified atmospheres[9, 13].

This project aims to develop a reliable, simple and economical control system for bin scale controlled atmosphere storage (using stick-on or clip-on control patches) that can be used widely by the Australian Chestnut industry. Recommendations for room controlled atmosphere storage will also be developed.

The impact on the industry of this research and its adoption is that a much higher quality chestnut will be available for much longer in the year. Also the ability to extend the storage times should allow exports to markets and during times of the year not currently possible.

Materials and Methods

Initially considerable testing and evaluation of the various components of the control system will be done. Options and performance of the components of the oxygen sensor, the air ventilator pump, battery or low voltage power and tubing will be evaluated. Also a simple electronic control system will be developed that will allow for reliable performance by calibration and monitoring via indicator lights and audible alarms. The aim is to develop stick-on or clip-on control patches that will reliably store up to 500kg of nuts sealed within bin sized plastic bags within a bin and stored in a cool room.

Secondly, the control system will be tested with small quantities of produce with similar respiration rates to chestnuts. It will then be tested with bin sized quantities of produce and further refined. Next, up to a dozen control systems will be tested during the 2003 storage season under commercial systems using quantities of up to 500kg of nuts with chestnut growers. Careful monitoring will be done through the season of both the condition of the nuts and the performance of the bags.

The results of each storage season will be used to refine the control system and then retested. Finally a reliable control system will be developed for commercial release, licensing and manufacture and widespread use by the chestnut industry.

Testing of the various unit configurations and of the results with chestnut storage was initially done at Sydney Postharvest Laboratory (SPL) and then also done at grower's properties. During the project research work was done with three grower's chestnuts Rinaudo's, Casey's and Nightingale's and two properties at Mount Stanley and Wandiligong in Victoria. The majority of the research with growers was at Highgrove, Mount Stanley, Victoria. The cultivar of nuts used in all this work was Purton's Pride, since that is most commonly used for storage. Where combined treatments of fungicides or sanitisers were used with CALM storage, the fungicide or saniotiser dipping was done first and the nuts then allowed to drain for at least four hours before storage in the CALM unit. Chlorine treatments were applied as a sodium chlorite dip at a level of 200 ppm active chlorine and the fungicide treatment was applied as a carbendazim (Spin Flo™, Nufarm Australia Ltd) at 250 ppm a.i. Either three or four replicates were used for each treatment, with each replicate consisting of 2kg of chestnuts held in an open weave plastic mesh bag. The results of each experiment were analysed using an ANOVA design by the Simstat statistics program (Provalis Research, www.provalis.com), for a Randomised Complete Block design, with differences between means compared using the Waller Duncan k ratio LSD rule at the k=100 level, which is approximately equal to the commonly used 5% level of significance.

Estimation of % external rot was done by measuring the percentage of rot shown on the hilum (softer area at the base of the nut). The shell of the chestnut rarely develops rot or mould as this is virtually confined to the hilum. Internal rot was assessed by cutting the nut across the equator and assessing the % of the internal area that was effected by internal rots. There was no development of external rots related to internal rots or of internal rots related to external rots.

Design of electronics and printed circuit board (PCB) design was done with the ExpressPCB program (www.expresspcb.com). The initial boards were produced at Sydney Postharvest Laboratory using double-sided photo resist PCB boards, but the latter series of boards were manufactured by ExpressPCB in the USA. Construction of all boards and units was done at SPL.

Results

Electronics

The first working board for the CALM system involved using multiple LED arrays as indicators. This is shown in the following first working circuit board (Fig.1) and in the pictures (Photo 1). The chestnuts were stored in commercial pallet bags within wooden half tonne bins, the bags were sealed with cable ties. The oxygen sensor used was a Teledyne R22D. Tests were made with 200 kg of chestnuts at 0°C and oxygen levels set at 2% oxygen.

The CALM system 2 involved the controller being stuck onto the plastic bag enclosing the nuts with a double sided adhesive sheet. The body of the oxygen sensor was within the controller box, with only the sensor surface within the bag of chestnuts. The large plastic bag sealed by twisting the bag and using a cable tie. This was along the lines of the original concept which was meant to be a stick on atmosphere patch (SOAP) to control carbon dioxide levels. A problem was found with the operation of the oxygen sensors in this configuration, since due to electrical heating of the power supply the temperature within the CALM unit was several degrees above the cool room and temperature of the chestnuts. The oxygen sensors used were sensitive to temperature, therefore, the oxygen levels measured by the oxygen sensor were higher than true oxygen levels. The sealing and oxygen sensor problems meant this configuration needed to be further refined. This was done for the location of the oxygen sensor in CALM System 2 (Photos 2 and 3), where the sensor was moved away from the rest of the electronics and placed within the bag

Fig. 1   First Working Circuit Board for CALM System (Board v3.2)

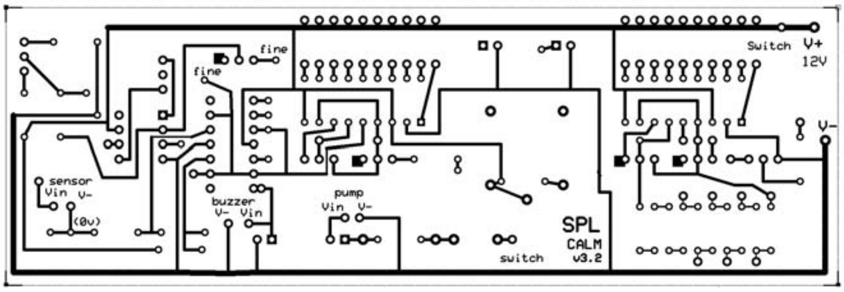


Photo 1   First Functional Working Board (Board v3.5) CALM System 2

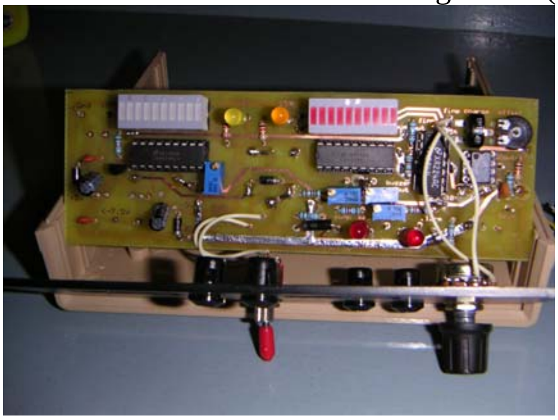


Photo 2 CALM System Version 3 with separate oxygen sensor

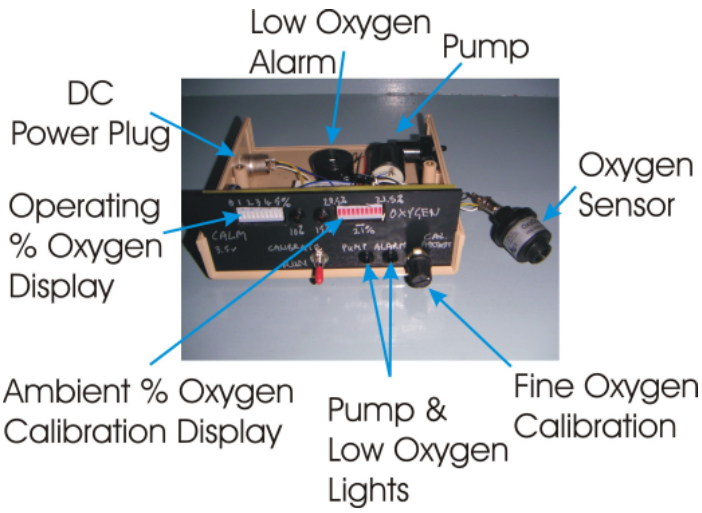
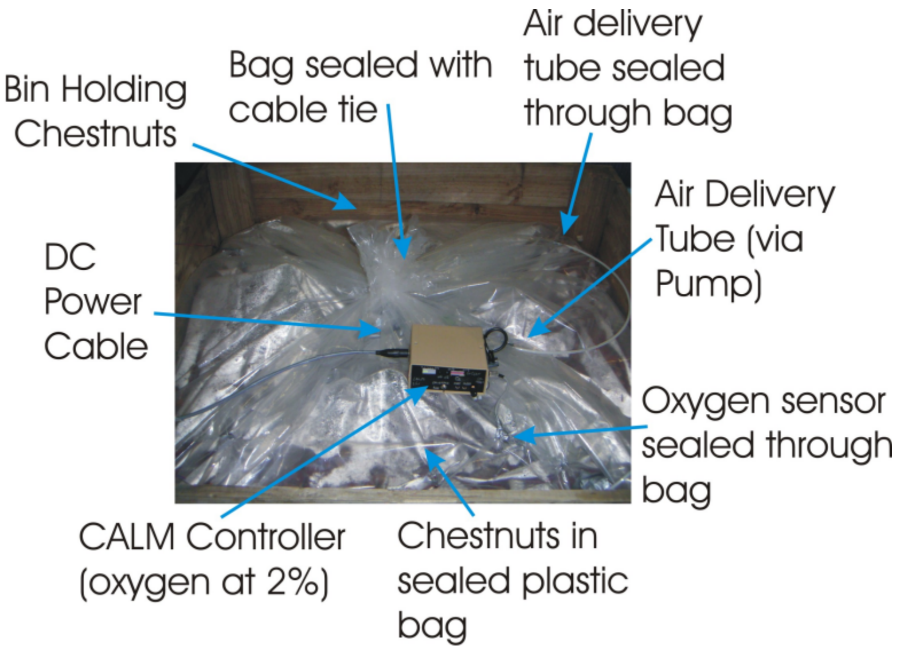
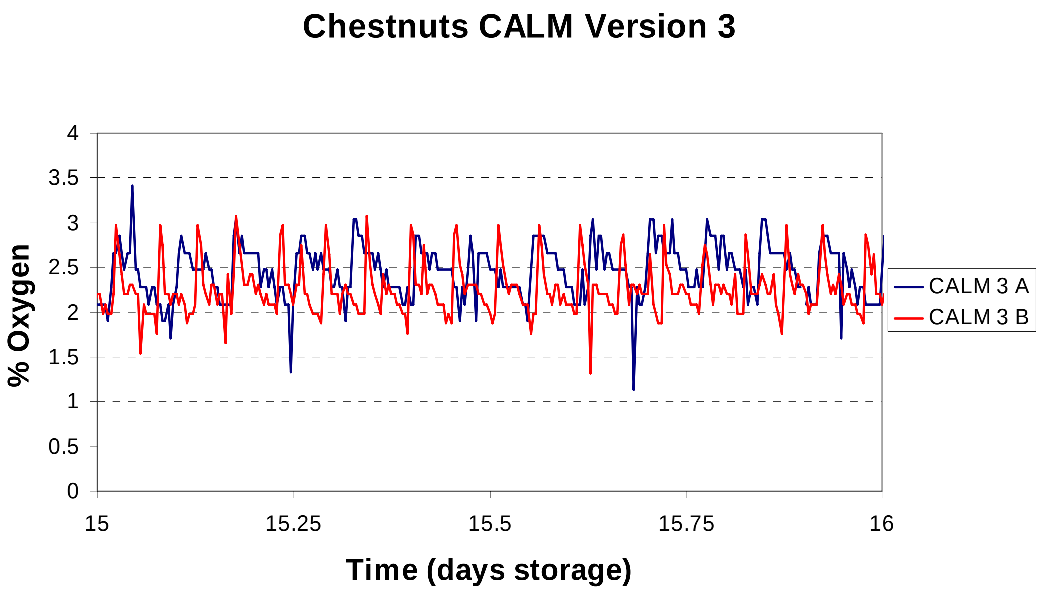


Photo 3 CALM System 3 Connected to Chestnuts



However, problems were still found with getting a complete airtight seal with CALM System 3 and consequently the desired carbon dioxide levels were not always continuously achieved. Figure 2 shows the oxygen levels maintained in two bags of chestnuts, these fluctuated between 1.5 and 3.5 % oxygen. For some of the nuts at the centre of the bags there was some off flavours noticed at these oxygen levels. Consequently for further testing it was decided to use higher oxygen levels (about 4%) and a better sealing method.

Fig. 2 Oxygen levels in two 200 kg bags of chestnuts stored with CALM Version 3

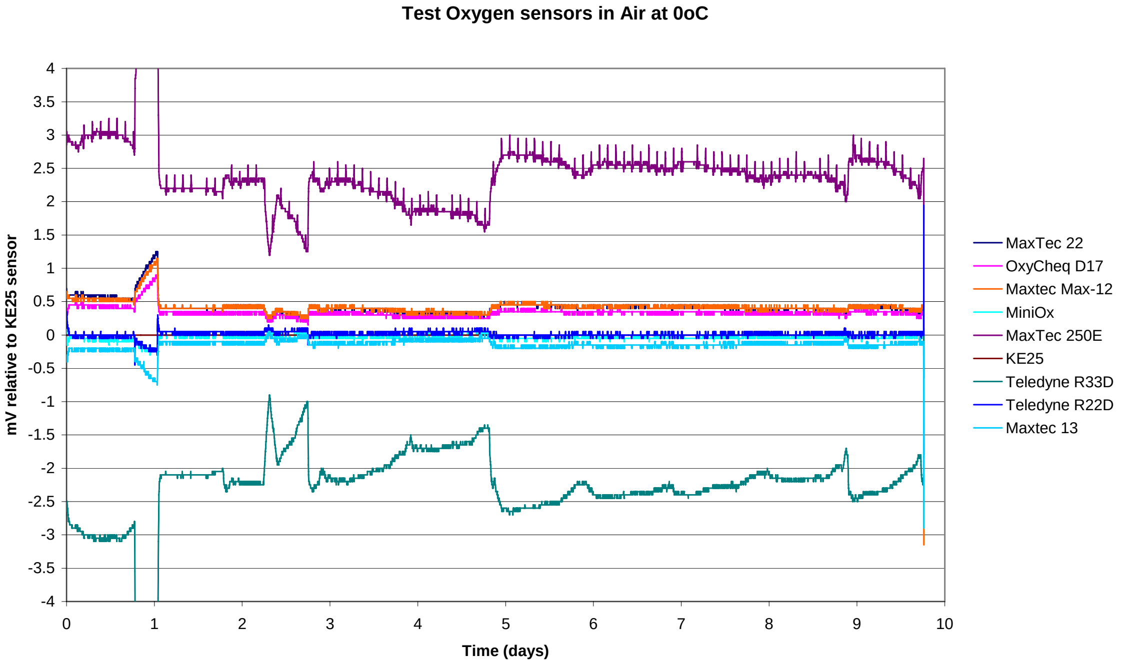


The CALM System 4 (Photo 4) involved the sealing being one by tying the plastic around a soft sealant strip surrounding the extension tube containing the sensor, this was done with a strong ratchet strap. Also the LED arrays used to indicate oxygen levels were replaced by a LED panel meter. The sensor operation in this model was greatly improved, but while the sealing method was reasonable once set up, it proved difficult to use.

Photo 4 CALM system 4 with separated oxygen sensor and seal though the neck of the bag.

In addition, there was a difference in reliability and accuracy of various oxygen sensors, consequently a sample of oxygen sensors were purchased and tested over a range of temperatures in air (20.95% oxygen). The results for the 0°C tests are presented in Figure 3. Most sensors perform similarly at 0°C, except for Teledyne 33D and Maxtec 22D. Over all the tests and especially at low temperatures, the best sensor was the MSA MiniOx sensor.

Fig. 3 Responses of oxygen sensors at 0°C in relationship to KE25 sensor.



The problems with sealing the unit to the bags, resulted in a major change of plan and the plastic bag instead of being within the wooden bins was moved to outside the wooden bins. The controller unit was then connected via an interface plate and pressure-tight seals, with a taped seal to a wooden base and cable tie at the top of the bag, or sleeve. Also the LED panel meter was replaced with a much less power consuming LCD. This was the first model (CALM V6) released to the Australian Industry (Photo 5). It has improved electronics and module design and works with lower power consumption. Further, with the new sealing and plastic bag/tubing configuration, this meant that instead of storing 250 kg with one unit in a plastic bag inside a wooden storage bin, one can store 4 bins (up to 1.6 tonnes) of chestnuts with the bins of chestnuts enclosed within a plastic tube. This system is illustrated in Photo 6 which shows several CALM units set up with four bins of chestnuts and running in a cool room. A detailed schematic is also shown in Figure 4.

Photo 5 CALM Model V6 sealed to chestnuts in plastic tube with interface plate

Photo 6 Several CALM V6 Units running showing the bins of chestnuts in plastic tube and sealed to pallet base.

Figure 4 Parts of CALM System

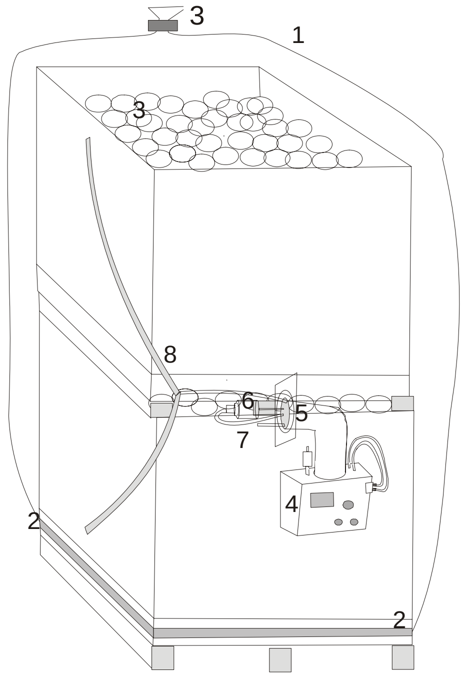


Figure 4 illustrates the basic features of the CALM system. The various elements are (1) the plastic bag (tube) to cover the chestnuts, (2) Pallet Base under storage bin (to which tube is sealed), (3) cable tie to seal top of plastic bag, (4) CALM unit, (5) Interface Plate (to connect unit to plastic tube), (6) Oxygen Sensor, (7) flexible tubing to add and extract air to plastic tubing (8) rigid nylon tubing to deliver air to the chestnuts farthest from the CALM unit. Also included is a 12V DC plug pack (so that only safe 12V DC power cables will be on the cool room floor).

Further modifications in CALM Version 7 following the experience of growers using the units involved a new sealing system at the base of the stack of bins (see Photo 7), also a smaller design with a better centre of gravity and indicator valves that show airflow during normal and calibration settings (Photo 8). Also important is a detachable pump (Photo 9) which is readily replaceable by growers during the storage season. This was necessary since pumps that were designed to last up to 5 years with one bin, were having to pump four times the originally envisaged amount of air and consequently needed replacing much more frequently than originally planned.

Photo 7 CALM V7 Sealing system on base plate, plastic is passed over the groove and secured by inserting a length of nylon rope around the groove.

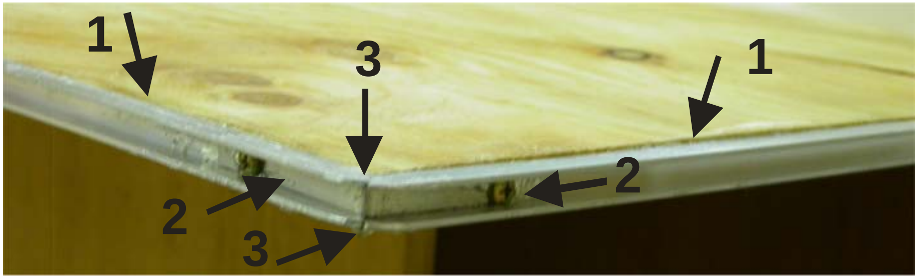
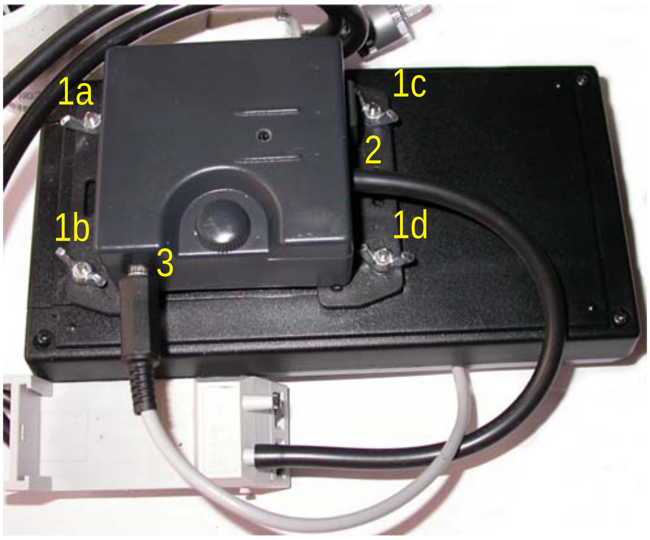


Photo 8   New CALM V7 controller and interface plate

Photo 9 Detachable pump for CALM V7, held on by wing nuts at 1a, 1b, 1c and 1d and connecting via tubing to the pump at (2) and via power cable from the pump at (3).



The latest circuit board for the CALM Version 7 is shown below (Photo 10). This is a significant improvement over the first circuit boards, being manufactured commercially with as a double sided board, with all holes plated through, silkscreen printing and solder masking, Solder masking was found to be very important to prevent problems in the damp environment of a commercial chestnut coolroom.

Photos 10 Assembled circuit board for CALM V7

The Benefits of the CALM System to the Chestnuts

The main problems of Australian chestnuts during storage are external and internal rots. These are shown in Photo 11a, 10b, 10c.

Photo 11 Main chestnut storage problems

a) Healthy chestnuts

b) External mould

c) Internal rots

The CALM system through maintaining a constant high carbon dioxide atmosphere around the chestnuts greatly reduces rots, especially external rots. This is seen in Figure 5, where after six months storage, the CALM system essentially controlled mould or rot levels at the same level as those initially found at harvest (ie ‘Initial’ treatment). There was a slight, but in this experiment, not significant improvement by also using sanitizers or fungicides. This excellent control of external rots was consistently observed. In most experiments internal rot levels were very low and consequently there was usually no significant control by the CALM system, or other disease treatments. However, in one experiment (Fig. 6) there actually was a significant level of internal rot and consequently it was possible to demonstrate significant control of internal rots by the CALM units. This control of internal rots is shown in Figure 6a, with the equivalent control of external rots in Fig. 6b. Each bin had a different ventilation rate, with the fastest ventilation rates in Bin 1 and the slowest in Bin 4. It was apparent that the faster ventilation rates of 1L/min or greater as used in Bins 1 and 2 (see extra column giving average for these two bins). Control in these two bins with their higher ventilation rates was more effective than lower ventilation rates of below 0.7L/min for Bins 3 and 4.

Figure 5 Control of External Rots by the CALM System (Version 3)

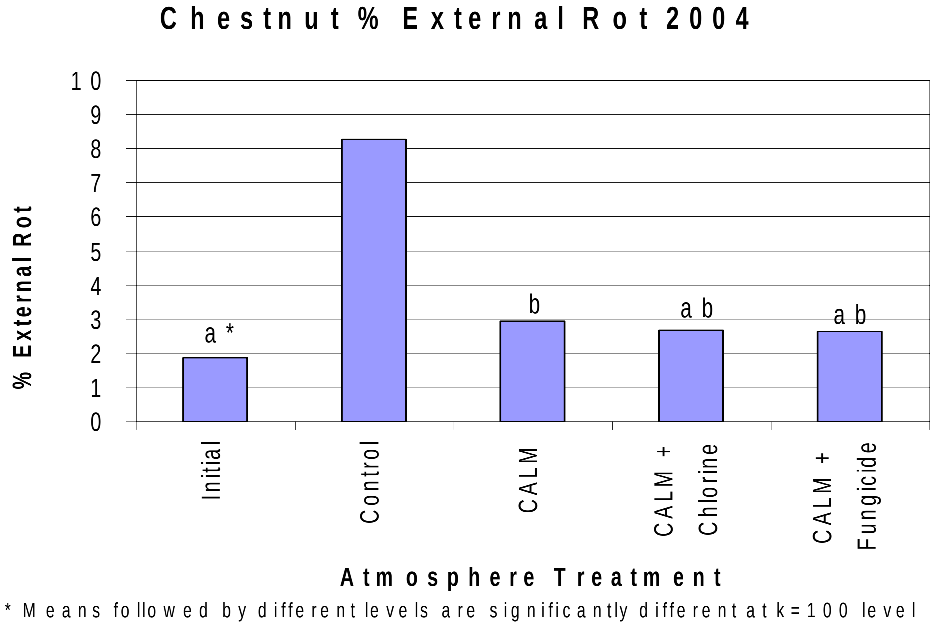


Figure 6a. Control of Internal Rots by CALM System Model 3 (2002)

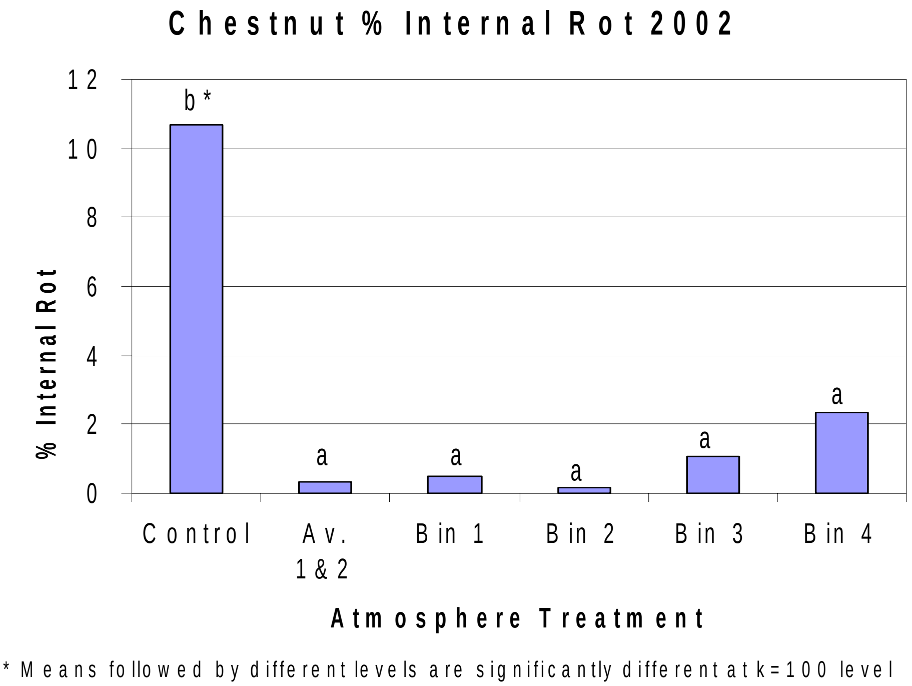
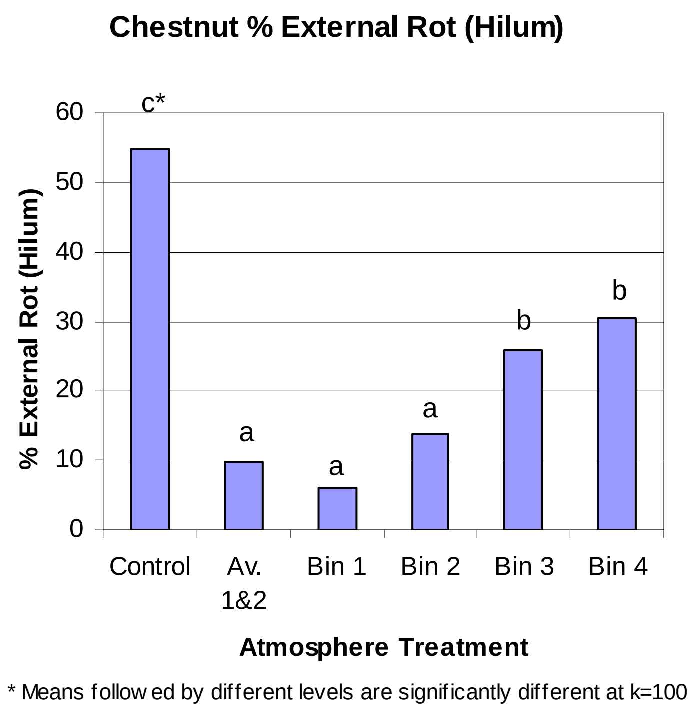
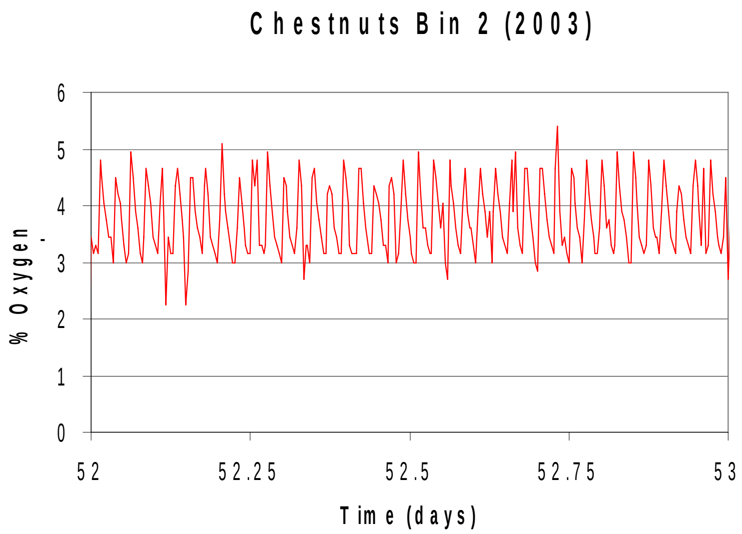


Figure 6b. Control of External Rots by CALM System Model 3 (2002)



The oxygen levels within the CALM system fluctuate within a range of values determined by setup of the CALM system and the volume of air within the system. The variation in oxygen levels for a CALM Model three unit is shown in Figure 7. The current unit runs within a much smaller range, typically from 4 to 4.5% oxygen.

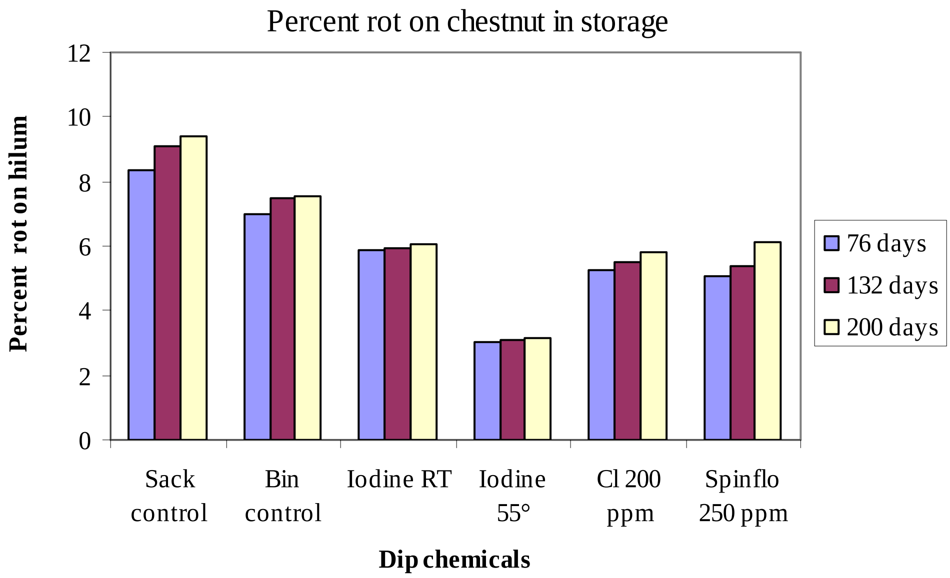
Figure 7 Oxygen levels within a CALM Model 3 system



The control of mould and extension of storage life is optimal if existing mould spores are eliminated with a sanitizer and the nuts dried slightly before putting into CALM storage conditions.

The effect of sanitisers or fungicides was checked in an experiment with chestnuts harvested in Victoria and transported to Sydney, these nuts were not stored under CALM conditions, but either stored in plastic lined sacks, or the remainder of treatments in plastic lined bins (Figure 8). It is obvious that the treatment of nuts with the sanitizers iodine and chlorine and also the fungicide Spinflo reduced mould levels considerably. The effect of treatment remained relatively constant over time. The best treatment by far, was the combination of heat and iodine, this was significantly better than fungicide.

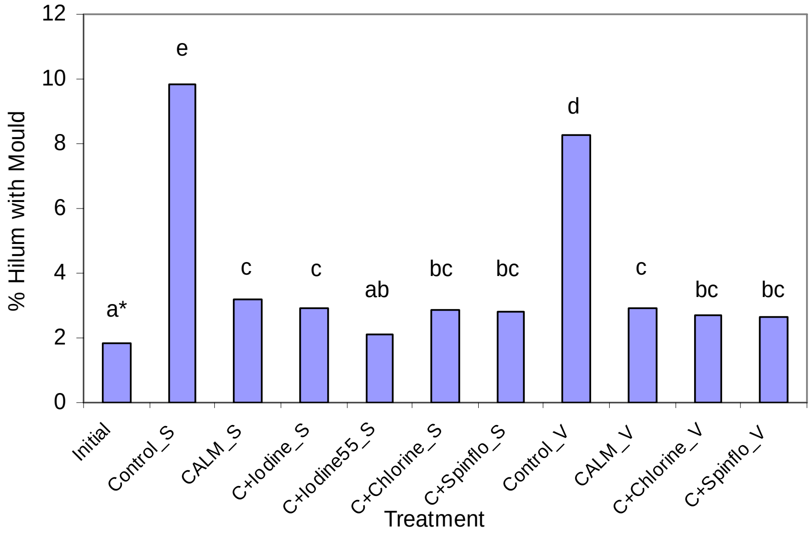
Figure 8. Effect of various treatments on chestnut external mould. Sack control in air, all other treatments in CALM. Iodine level was 30 ppm. The k LSD ratio level for significant difference between treatments was 1.2%.



A further experiment was carried out combining the CALM storage treatment with other disease control measures. Without any control mould levels were high. In Figure 9a without any treatment mould levels in the chestnuts transported to Sydney increased from 1.7 to 9.8% and the nuts held on the growers property in Victoria increased from 1.7% to 9.1%. The use of sanitisers, fungicides or CALM storage alone only permitted mould to increase to about 3%. However, combining the best sanitizer and CALM, meant that there was no significant increase in mould after 3 months storage at 0°C. Levels of internal mould Fig. 9b were so low that no significant differences could be observed.

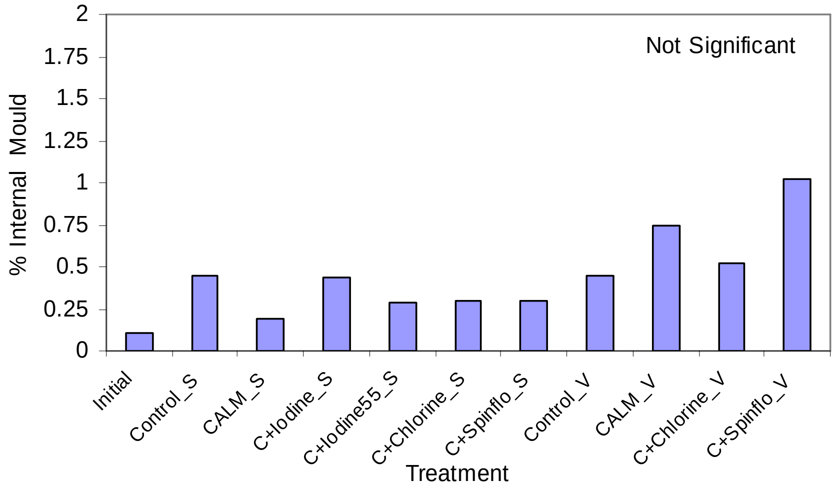
Figure 9 Levels of moulds and rots in chestnuts harvested in Victoria and either stored in Victoria (V) or transported to Sydney and stored at SPL (S) after 3 months storage, 76 days of Storage at 0C. C= Calm 4% oxygen, Iodine = 30 ppm, Spinflo at 250 ppm a.i.

A External Moulds



* Means with different letters are significantly different at kLSD = 100 level

B Internal Rots



Discussion

Several years of research has shown that the CALM system combined with careful preparation of the chestnuts prior to storage gives excellent extension of storage life. The main benefit is on reduction of external mould on the soft hilum. The long term costs of operating the CALM unit will only be precisely know after several years experience. However, based on current experience one could estimate the CALM unit lasting about 6-9 years (including the pallet base and interface plate), the oxygen sensor, air pump and DC power supply needing replacing every two to three years and the plastic bag replacing every one to two years. Based on these estimates and current prices, the cost of storing with this system would be about \$150 to \$250 year to greatly reduce external and internal rots and greatly extend the storage life up to 8 to 10 months if required. For a stack of approximately one tonne, CALM storage costs are then estimated as 15 to 25 cents per kilogram. Besides this amount, the only costs to the farmer are a few dollars of electricity, a short time to set up the bins and regular (preferably daily) checks during storage to ensure the units are connected to power and working normally.

The normal methods of storage in Australia are basically simply the use of cool storage, with some packaging or lining of storage containers to reduce weight loss. There is little of no use of specific postharvest treatments to limit postharvest rots, consequently conventional storage only permits storage for one or two months.

It is recommended that the CALM system be applied in conjunction with a complete postharvest program as set out in the article attached as an Appendix. This in short involves

- harvesting nuts carefully with minimum damage and moving quickly to the shed
- using a sanitizer or hot water/sanitizer to cleanup any infections
- holding the nuts for several days in open bins under cool storage to allow slight loss of water (~1-3%)
- storage using the CALM system
- running the cool room at -2°C to ensure best storage conditions within the CALM system

(N.B. Royalties from the sale of each of these units go to CGA and HAL as a continual return on their research investment)

The chestnut production in Australia according to the most recent statistics of 2002/2003 was 1,720 tonnes, with a Farm Gate price of $5.1 million and exports of $18,000 (HAL, Australian Horticulture Statistics Handbook 2004). These exports were very low and current production and especially export levels are much higher. The losses during storage without the disease control achieved by CALM systems would be at least 10 – 15%. This would then be about $0.5 to 0.8 million dollars. The use of the CALM system (together with other suggested procedure changes) would be expected to reduce these losses by at least 2/3rd, giving a total potential benefit to the Australian industry of $0.3 to 0.6 million dollars. The cost of a CALM is about $1,000, with increased returns from each system already established as worth at $1,000 to $5,000 per annum.

Technology Transfer

To date we have made presentations at several field days and also talks at conferences. We have also produced an article outlining the recommended handling system to go with CALM storage, as well as an article giving an overview of CALM . These articles have been sent to most customers and are available on the SPL website (see attached articles).

The adoption by the industry was good over the first two years of availability, with a majority of larger growers purchasing units. Sales this year have been disappointing, however, the drastic conditions due to the drought this year have meant that many farmers have very large reductions in harvests and many have no nuts to store.

At present we do not have a commercial partner licensed to manufacture the CALM units, as numbers are modest. Once large numbers of units are being sold to the Chestnut industry in Australia and particularly sold to overseas, a commercial partner should be practical.

Current Status of Commercialisation Process

The provisional patent for this technology was lodged on 18 January 2005 and entitled "Controlled Atmosphere – a method, system and apparatus for maintaining a controlled atmosphere around horticultural produce" Provisional patent application no. 2005900216.

Sales to date have been

CALM systems Version 6 - 30 units

CA/lm systems Version 7	-	13 units
CALM Version 6 upgrade	-	19 units
Pumps	-	62 units

Sales to date have been all to Australian growers or marketers of chestnuts, except for one unit sold in mid 2006 to a USA chestnut grower. Unfortunately, sales of units in 2007 were minimal since most chestnut growers had disastrously low harvests due to the drought and most growers had virtually no nuts for long term storage. It is hoped that sales in future years will pick up significantly as the Australian chestnut industry recovers.

It is planned to follow up on very successful results in the USA with the CALM system with a visit in August/ September to demonstrate the system and hopefully encourage many extra export sales.

Royalty payments to HAL have been completed for 2005/2006, but not yet calculated and made for 2006/2007.

Acknowledgments

Thanks to the Chestnut Growers of Australia Ltd for funding this project. Together with practical support and advice from many growers, especially Joe Rinaudo, High Grove, Stanley, Brian and Jane Casey, Cheznuts, Eurobin Victoria and Nightingale’s, Wandiligong. Special thanks are due to Dr Jenny Jobling at Applied Horticultural Research for her professional and scientific advice and contributions to the research.

The following students are thanked for their assistance with the experimental work: Stephane Saint-Pierre, Frederike Sibylle, Irene Strasser. Financial support from Horticulture Australia Limited is gratefully acknowledged.

Technology Transfer ARTICLE 1

Recommended Postharvest Handling and Storage Protocol for Chestnuts

(based on Sydney Postharvest Laboratory (SPL) research and other research and industry experience)

Taken from Sydney Postharvest Laboratory Web Site (www.postharvest.com.au)

Harvesting and Handling

- Harvesting and handling should be done carefully to avoid damage, both to the shell of the chestnut and the tufts at the tip of the chestnut, that can provide a means of access of fungi into the chestnut.
- Minimise the amount of extra plant material and dirt brought into the packinghouse with the chestnuts. Minimise the amount of extra plant material and dirt brought into the packinghouse with the chestnuts.
- Bring nuts back to the shed as soon as possible and sort and cleanup then and put into coolroom.
- Tip chestnuts carefully from bins avoiding transferring any mud and removing excess leaves, grasses, burrs etc.

Postharvest Dipping

- Several postharvest disease control treatments are effective, ranked in order of effectiveness these are
    - o Iodine at 30 ppm a.i. at 55ºC for 2 min (registered for Aust. chestnuts)
    - o Carbendazim at 250 ppm a.i. for 1 min (Spin Flo) (not registered for Aust. chestnuts)
    - o Chlorine at 100 ppm a.i. and 7.5 pH (sodium hypochlorite) for 1 min (approved for Aust. chestnuts)
    - o Peracetic acid at 100 ppm a.i. (Tsunami or Vortexx) for 1 min (approved for Aust.chestnuts).

(Other postharvest disease control measures that have been reported as effective, but not tested on Australian chestnuts are

- o Water curing which involves holding chestnuts under water at ambient temperatures (~15ºC) until fermentation starts (bubbles given off) in 3 to 9 days.
- o Heat treatment holding at 50ºC for 30 – 45 min)

During the dipping process remove any floating chestnuts

Slight Water Loss before Storage

When freshly harvested, chestnuts contain slightly higher water content than optimal for long-term storage.

- Therefore it is recommended that after any water dipping the nuts be allowed to fully drain at ambient temperature for several hours
- Before subsequent packaging or storage, the chestnuts should be left in open bins in the cool room for 3 days

These two measures should result in the loss of a few % moisture content (or 1-4% of total weight) and will greatly assist with final quality

Storage

- The best temperature for storage of chestnuts is just below freezing at -2ºC (28ºF) (if all the nuts in the coolroom are stored under the CALM system, set at -3ºC (26ºF), as the temperature in the plastic is about 1ºC above coolroom.)
- The best method for preventing weight loss and especially minimising rots during storage is to store enclosed in plastic bags with a high carbon dioxide atmosphere (>15%). Such an optimum storage environment is provided by storing chestnuts using the SPL developed CALM system. In addition, the modular nature of the system means that each modular unit can be opened to market the 0.4 to 1.6 tonnes of chestnuts without disturbing the other chestnuts under storage with CALM units.
- If the nuts are intended for short term storage or marketing, then packaging in perforated plastic bags or tightly woven polypropylene bags is recommended.

Providing the above protocols are followed, then storage of premium quality chestnuts with virtually no external rots, extremely little weight loss and no sprouting for 10 months or longer is possible.

(It should be noted that while high carbon dioxide storage atmospheres will give significant control of internal rots (such as Phomopsis), control is not as effective as for external moulds).

If you have any queries please email spl@postharvest.com.au or ring +6194908443 (02 9490 8443) or +61410603170 (0410 603 170)

Technology Transfer ARTICLE 2

Taken from Sydney Postharvest Laboratory Web Site (www.postharvest.com.au)

CALM Chestnut Storage Technology (formerly SOAP)

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Summary

- Developed over the last 3 years by Sydney Postharvest Laboratory with Chestnut Growers of Australia (CGA) and Horticulture Australia (HAL). The final design has been finalised and is now protected by a patent.
- The basic principle is storage under high carbon dioxide with adequate oxygen levels maintained.
- Enables excellent long term control of rots in chestnuts without use of chemicals for periods of up to 12 months. Cost of running each unit (which can store up to 1.5 tonnes) is about A$220/year.

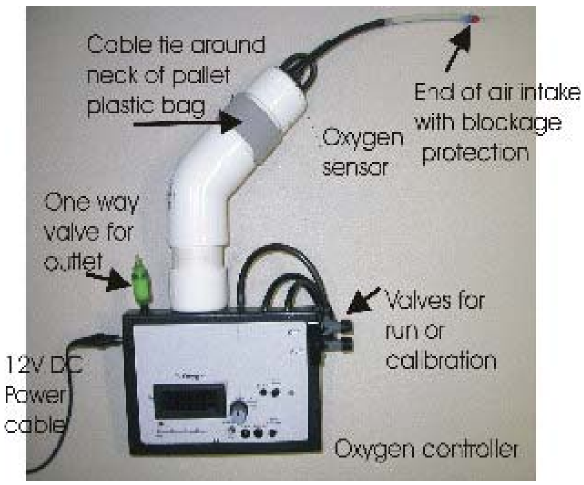
Background

This technology was developed out of very promising controlled atmosphere (CA) work that was done supplementary to the original HAL chestnut postharvest project. It has involved lots of work on the best oxygen/carbon dioxide levels, testing different components for reliability and suitability and developing the best sealing systems.

First Model

Stick on controller, oxygen sensor in controller, cable tie bag

Second Model



Sealing by cable tie around soft strip, sensor within bag

Third Model

Interface plate, pressure fit interchangeable connectors, sensor in bag, bag in bin

Fourth Model

Same as above but bag outside the bin or bins, need to set on solid base and seal bag at bottom and top.

Current Model

Figure 1

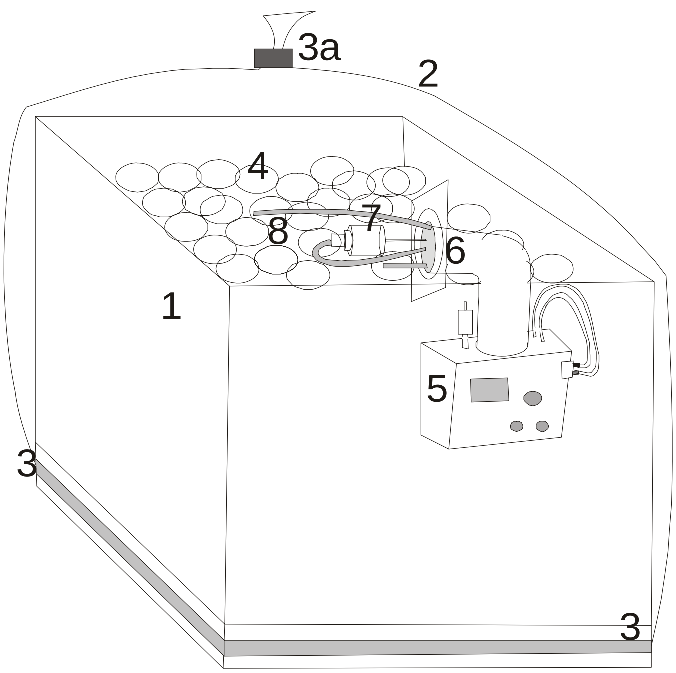
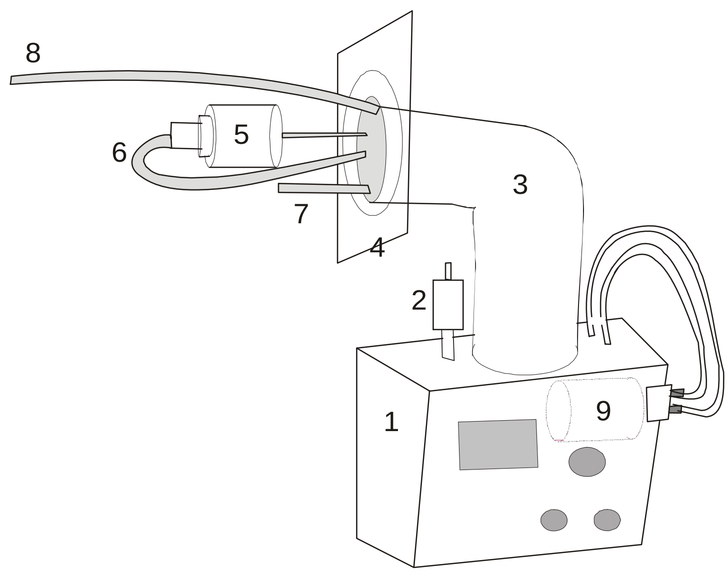
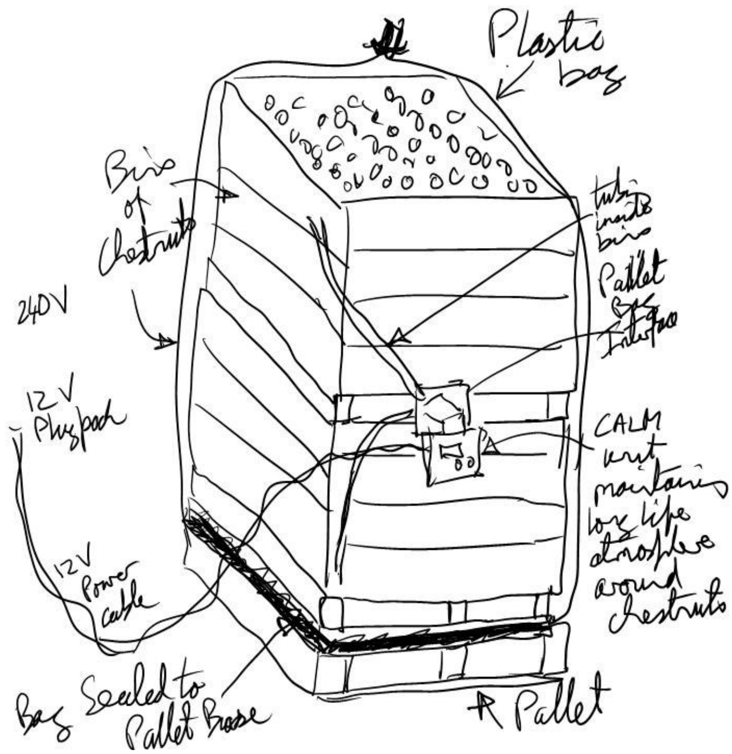
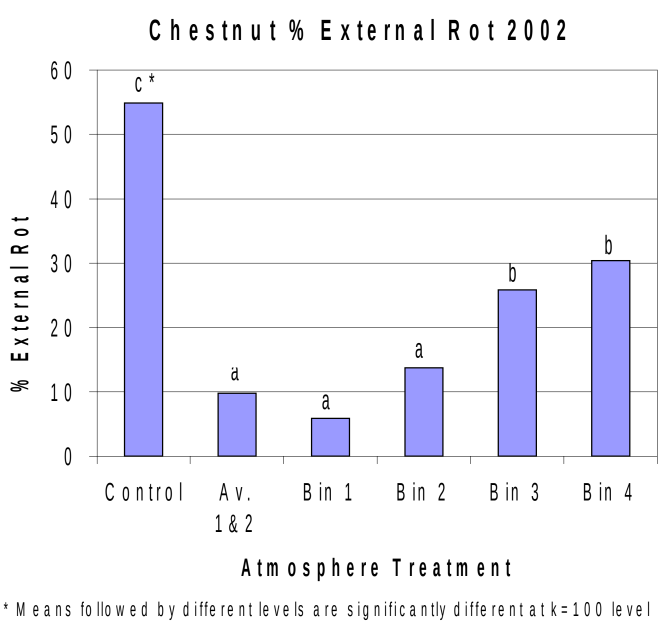


Figure 2

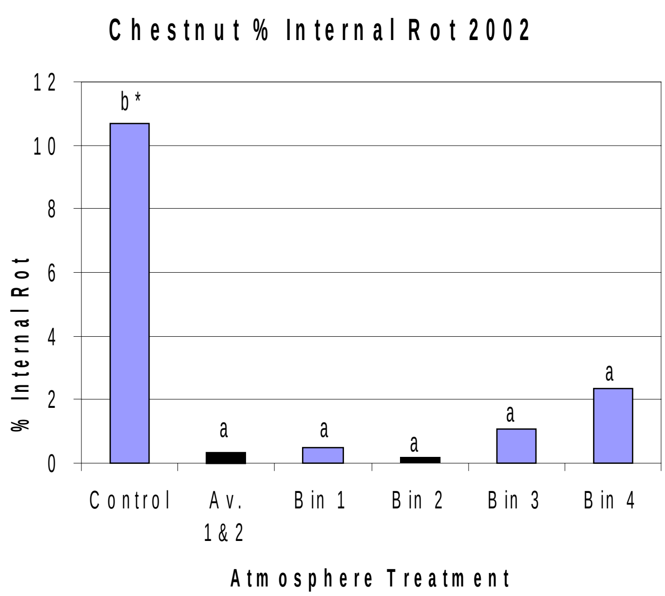




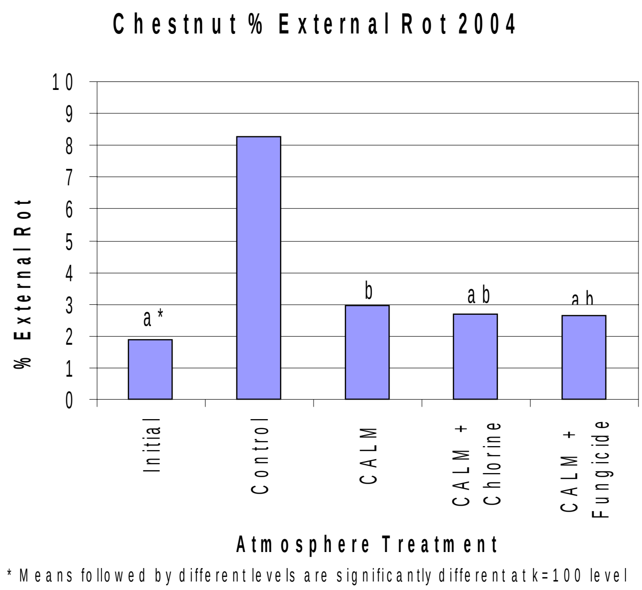
Benefits of Technology



* Means followed by different levels are significantly different at k=100 level



* Means followed by different levels are significantly different at k=100 level



Details of Current Model

Each unit can be used to store 1 to 4 bins (400 to 1600 kg) of chestnuts.
The bins of chestnuts are placed on a pallet base which seals the bottom of the bins, a plastic sleeve is placed over the bins and sealed at the pallet base and tied at the top. A pallet bag interface is then attached to the plastic bag at the top of the second bin, the CALM unit seals to the pallet bag interface, with air oxygen sensor and tubing going through the interface to provide just enough fresh air to the chestnuts to maintain the ideal storage atmosphere. The CALM unit is powered by l2V DC, so that only safe, low power cables are used within the cool rooms.

The CALM unit should last 6-9 years, as should the pallet base. The oxygen sensor needs replacing every three years, as probably would the DC power supply, the plastic bag and pump would probably last two years if handled carefully. Based on these conservative estimates the cost of storing with this system would be about A$160/ tonne/year, to greatly reduce external and internal rots and greatly extend the storage life up to 8 to 10 months if required.

Besides this amount of about A$160 per tonne per year, the only costs of storage are a few dollars of electricity, a short time to set up the bins and regular checks during storage to ensure the units are connected to power and working normally.

[CALM Chestnut Storage Main Page](http://www.postharvest.com.au/CALM.htm)
[(http://www.postharvest.com.au/CALM.htm)](http://www.postharvest.com.au/CALM.htm)

Recommendations

It is recommended that progress continue with publicising the CALM unit both in Australia and especially overseas. This should boost numbers of units being sold to sufficient levels to get units made with a commercial partner.

It is also recommended that research continue as rapidly as possible to expand the technology to other fruit and vegetables that would benefit, such as berries ie strawberries, summerberries and some soft summer fruits such as cherries.

Acknowledgments

We wish to acknowledge the extensive help of CGA and numerous chestnut growers in this project, especially Joe Rinaudo and Brian and Jane Casey. Also the assistance of Ed Cousins with electrical circuit design is greatly appreciated.

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