

Postharvest Handling of Fresh Vegetables

**Proceedings of a workshop held in Beijing,
People's Republic of China, 9–11 May 2001**

Editors: Tim O'Hare, John Bagshaw, Wu Li, and Greg Johnson

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Foreword

WHEN the ACIAR project on postharvest handling of leafy vegetables that led to the workshop reported here was conceived, the remarkable changes in marketing systems for vegetables in China were only just beginning. The project developers thus showed considerable foresight in incorporating not only technology development, but also process mapping to identify gaps and needs in the chain between producer and consumer.

Since 1998, the Chinese and Australian project teams have had important opportunities to identify and address technology needs for marketing systems that have been changing year to year. As a result, the capacity for researchers in China and Australia to continue to provide dynamic technological solutions to constantly changing requirements has been considerably enhanced and I would like to commend all concerned with the project for both the opportunities and the outputs of their collaboration.

The project has examined the postharvest management of several key vegetables in China and Australia, and has generated options for enhancing their postharvest quality. It has been part of ACIAR's strategy to boost research and development investment in the postharvest sector, recognising that there was a critical need to both reduce losses, and extend the storage life and quality of vegetables in urban markets.

This workshop provided an opportunity to fully report on the project outcomes. It also introduced new research challenges that have been proposed in the fields of postharvest handling of melons and in improvements to microbial safety of fresh vegetables. Thus, we have coverage of not only what has been done, but also of what lies ahead.

Distribution and processing systems have played a significant role in the evolution of modern society over the last century. They are the means by which both developed and developing countries will bridge the gap between the haves and the have-nots of our society. They link the farmer to the towns, and the towns to the world.

When visiting a remote village in Jilin Province in northeastern China in 1998 to observe local government elections, Friedman (1999)¹ noted that, amongst the usual promises to the electorate of the two candidates for mayor, one candidate promised to get the villagers' vegetables to the township more quickly, while the other promised to give everyone the technology for making bean curd! Which candidate won? The one who promised to get the villagers' vegetables to the township!

Greg Johnson
Postharvest Program Manager,
Australian Centre for International Agricultural Research

¹ Friedman, T.L. 1999. *The lexis and the olive tree*. New York, Farrar Straus Giroux, 394p.

Preface

THIS workshop on postharvest handling of fresh vegetables was organised to highlight the impact of postharvest practices on the quality of vegetables reaching the consumer. It follows on from ACIAR project PHT/1994/016, 'Extending the shelf life of leafy vegetables', which included analysis of the current postharvest handling systems around the Beijing municipality, and in Zhejiang and Shandong provinces, in China.

The workshop was designed to provide an opportunity for postharvest specialists from China and elsewhere to discuss problems facing a number of commodities, and to build links between institutions to help solve these problems. To allow the full and efficient exchange of information, simultaneous translation during the workshop made all presentations available in both Chinese (Mandarin) and English.

Small group discussions were scheduled at various times during the workshop to brainstorm the main priorities for vegetable postharvest research and development in China. Key issues raised included:

- the need for technologies appropriate to cost structures in an industry;
- more emphasis on the whole postharvest handling system from farm to consumer;
- training and education of industry people and support staff;
- improved packaging and transport systems;
- improved storage technology for long-term storage of leafy vegetables;
- improved postharvest disease management;
- food safety;
- value-adding and processing;
- marketing strategies and supply-chain management; and
- export market access.

These and other issues were discussed in great detail at the workshop.

One of the benefits of a workshop such as this is the opportunity that it brings for postharvest specialists from a wide range of backgrounds to interact and develop closer linkages between the organisations they represent. It is our hope that this workshop has contributed to development of collaborative activities to improve postharvest handling of vegetables in China and elsewhere.

We thank the Australian Centre for International Agricultural Research (ACIAR) for sponsoring the workshop and publishing the proceedings. We also thank the Beijing Vegetable Research Center (BVRC) for organising the workshop, and all presenters and participants for their enthusiastic involvement.

The Editors

Opening Address

Wang Shixiong

Deputy Director, Beijing Municipal Commission for Science and Technology

Dear guests, ladies and gentlemen,

On the occasion of the opening of the workshop on postharvest handling of fresh vegetables, please allow me to extend warm congratulations on behalf of the Beijing Municipal Commission for Science and Technology. We welcome guests and representatives from the Australian Centre for International Agricultural Research and other organisations both from home and abroad.

Beijing, the capital of China, is a cosmopolitan city. Both vegetable production and supply play crucial roles in the Beijing market. Along with improving people's living standards and China's upcoming access to the World Trade Organization, both domestic and international markets require us to provide high-quality vegetable products. Postharvest technology will be very important in this regard.

China is rich in horticultural crop varieties. Vegetable acreage and output rank among the highest in the world. Exports of fresh vegetables and various processed vegetable products in recent years have been on the rise. Vegetable acreage in the suburbs of Beijing registered 60,000 hectares in 2000. Apart from supplying local markets, exports to other countries and other parts of the country reached 350,000 tonnes.

Agricultural modernisation of Beijing has been set as the principal target for future development. Industrialised, high-efficiency, agricultural demonstration projects conducted in recent years have promoted greatly the modernisation of Beijing vegetable production. Beijing is an important centre for research and extension of vegetable breeding, cultivation, and postharvest processing. Scientific progress in recent years has contributed a great deal to the production and supply of vegetables in Beijing.

International cooperative research projects and academic exchanges are important to the development of Beijing agriculture. Acknowledged experts and scholars both from home and abroad in the field of postharvest are attending this workshop. I hope the workshop will facilitate cooperation between the Australian Centre for International Agricultural Research and Beijing in postharvest handling of vegetables, and enhance research and the extension of postharvest technology.

May the workshop be a great success.

Thank you.

Problems and Countermeasures in Postharvest Handling of Fruits and Vegetables in China

S.Q. Feng*

Abstract

China is a large agricultural country and one of centres of origin of fruit. More than 30 species of fruits are produced for economic purpose, such as apple, citrus, pear, grape, peach, pineapple, lychee, longan, mango, banana etc. At the present level of fruit production, China has become the second largest producer in the world. Both her apple and pear production rank first in the world, and citrus production third. China is also one of the centres of origin of vegetables and is the world's largest producer of vegetables. However, the development of agriculture still faces great challenges, including the growing population, the continuously rising consumption level, the increasing demand for agricultural produce, the continuous shrinkage of farmland, the decreasing agricultural resources, and severe postharvest losses that need to be overcome.

The paper will deal with the postharvest problems encountered in agricultural products, especially fruits and vegetables. Topics to be covered include postharvest handling, storage methods, postharvest losses, packaging, food distribution, shelf-life extension, and some problems associated with social customs. It will introduce various aspects relating to the background, present situation, countermeasures, development, future targets, and international cooperation in the postharvest area.

IN China, agricultural research so far has been mainly concentrated on the improvement of crop production to achieve self-sufficiency in food in order to support the growing population. It is claimed that, in the near future, the food supply problems will be more complex as patterns of food consumption have improved in the region along with rising incomes and social development.

Postharvest technology should be given more emphasis, so as to prevent crop losses and use agricultural products more efficiently to meet the changes in the food demand, especially the demand for processed foods. The development of postharvest technology could contribute to securing a stable supply of food products in addition to an increase in agricultural income and improvement of the diet in China.

* Chinese Agriculture University, Beijing 100094, People's Republic of China.

Fruit and Vegetable Production

China is one of the centres of origin of fruit in the world and is recognised as the 'cradle of the orchard'. There are more than 300 species of fruit trees throughout the country and more than 30 species of fruits produced for economic purposes. They include apple, citrus, pear, grape, peach, jujube fruit, plum, apricot, hawthorn, kiwifruit, cherry, strawberry, banana, pineapple, lychee, longan, mango, red bayberry, coconut, and papaya.

Since the founding of the 'New China', the people's government has paid great attention to fruit production and has taken a series of effective measures so that fruit production has recorded a rapid development. Especially since the reform and opening-up policy and the lifting of restrictions on fruit markets, the enthusiasm of farmers for fruit production has markedly increased. Fruit production has contributed to crop production and become one of the major sectors in the

rural economy. By the end of 1994, China was devoting 7.264 Mha to fruit production, with an output of 35 Mt, increasing by 3.4 and 4.3 times, respectively, against the level of 1978. By the end of 1995 and 1996, fruit output was 42.15 and 46.53 Mt, respectively, and by 1998 and 1999, had reached 53.92 and 62.37 Mt.

At the present level of fruit production, China has become the second largest producing country in the world, with both apple and pear production ranking first in the world and citrus third. The outputs of apple, pear, and citrus were 11.13, 4.04, and 6.81 Mt, respectively, by the end of 1994. The outputs of apple, pear, citrus, and jujube fruit were 19.18, 8.59, 7.27, and 1.1 Mt, respectively, by the end of 1998. The outputs of apple, pear, citrus, grape, banana, jujube fruit, pineapple, and persimmon were 20.8, 7.74, 7.27, 2.7, 4.19, 1.1, 0.64, and 1.31 Mt, respectively, by the end of 1999.

China is also one of the centres of origin of vegetables and is the world's largest vegetable-producing country. Some 9.6 Mha of land are devoted to vegetable production, with an annual output of 2.4 billion tonnes by the end of 1995, rising to 4.05 billion tonnes by the end of 1999. Chinese cabbage, cucumber, tomato, flowery cabbage, glassy cabbage, purple cabbage, broccoli, eggplant, celery, potato, mini tomato, peppers, peas, lettuce, melons, mushrooms, chicory, kale, brussels sprouts, asparagus, and mini radish are among the most popular vegetables. More than 70 varieties are supplied to consumers and about 40 varieties can be marketed all the year round.

Postharvest Technologies and Problems

Lack of storage facilities and postharvest investment

The postharvest losses are still serious with a percentage of more than 35% in China. Although state financial support to agriculture has increased by 54 times and agricultural credit by nearly 26 times, the investment in postharvest technology is still very low compared with other sectors. State investment in postharvest technology is only 0.38% of that invested in production.

As living standards rise, people are seeking a greater variety of fruits and vegetables of higher quality. However, most fruits and vegetables are still stored in conventional warehouses, underground storehouses, and cave houses. The shelf life is usually very limited and the quality cannot be guaranteed.

There was no refrigerated storage for fruits and vegetables in 1950s. The first refrigerated storage for fruit was built in 1968 and the first controlled atmosphere (CA) storage in 1979, with a total capacity for storage by these means of less than 100,000 t at that time. At the beginning of the 1980s, refrigerated storage of fruits and vegetables increased rapidly, especially after the lifting of the restrictions on fruit marketing. The total storage capacity reached more than 6 Mt by the end of 1994, including 2.27 Mt of refrigerated and CA storage capacity. However, not all of the CA storage is operational because of technical problems including lack of fuel for some of the atmosphere-generating systems. Therefore, most fruits and vegetables destined for the market deteriorate very quickly after harvest. For example, only about 25% of apple production was put into some form of storage.

The situation and problems of postharvest techniques, handling, and transportation

There has been a remarkable development of storage technology and facilities over the past 10 years. Various types of CA equipment with good and reliable performance are now being designed and manufactured in China. Apple and garlic stalks stored by CA for 10 months fulfilled the quality requirements of international and domestic markets and were sold at a good price.

Modified atmosphere (MA) technology developed in China is now widely used. This includes: individual film wrapping of citrus fruits, cauliflower, broccoli, and other fruits and vegetables; storage of garlic stalks in large plastic bags; and tent storage of apples, garlic stalks, and other fruits. Using the MA technique, garlic stalks can be kept at a temperature of 0–1°C for 9 months with losses of about 5%. The firmness of apples stored by this technique in caves could be maintained at a value above 5.5 kg and the losses were less than 4% after 6 months of storage. MA packing storage provides a method that requires minimum capital and energy, and is not expensive to operate.

Although the production of fruits and vegetables is large, the quality of much of the output falls after harvest, because of poor postharvest handling. Treatments such as cleaning and washing, trimming, grading, sorting, pre-cooling, waxing, disease control, and suitable packing are usually not implemented before transportation, marketing, and storage. Most of fruits and vegetables are transported directly to market as raw products with no packaging whatsoever. Nevertheless, people have begun to pay increasing atten-

tion to postharvest handling. During the 1990s, over 40 sets of automatic washing, grading, waxing, and packing lines for citrus and apple were imported into several large production and commercial storage areas for fruits and vegetables.

China is a very large country. Most fruits and vegetables are transported by road without refrigeration. To reduce the temperature of fruits and vegetables, crushed ice is put between the products in the car during long-distance transportation. There are very few refrigerated vehicles for transportation of horticultural produce between provinces in China. Of the about 4200 refrigerated cars and more than 7000 refrigerated and insulated vans, most are used for transportation of agricultural products such as meat, poultry, fish, and eggs.

Owing to the poor transportation system, the total losses in transit can amount to more than 15–35%.

Recommended quality and packaging standards for several kinds of fruits and vegetables have been introduced. Commodities covered by these include apple, pear, kiwifruit, grape, tomato, cucumber, sweet pepper, egg plant, lettuce, Chinese cabbage, celery, broccoli, pod bean, and spinach. However, enforcement of the regulations is limited, except for export products. Most of packages currently used for fruits and vegetables are made of plant materials, for example, bamboo baskets, and are not suitable for soft products and stacking. Mechanical injury of fruits and vegetables is serious with the packages. Now cartons, and wooden and plastic boxes are used more commonly in storage and transportation in large cities.

Problems Existing in Agricultural Development and Future Targets

The development of China's agriculture faces great challenges such as the growing population, the continuous increase in the consumption level, the increasing demand for agricultural produce, the continuous shrinkage of farmland, and the decrease in agricultural resources. By the middle of the century, the population of China will reach 1.5–1.6 billion. While China is overall generally well endowed with resources, on a per capita basis the circumstances are not so favourable. For example, the area of land available per capita is only one-third of the world average.

Facing the aforementioned challenges, the Chinese Government has determined that it cannot import large quantities of agricultural products. Therefore, China

must adopt a strategy of self-reliance and integrated development, adhere to the national policy of family planning, expand rural reform and the opening-up policy, strengthen the international cooperation, develop and utilise land and other agricultural resources in a scientific and rational way, and preserve the agro-ecological environment.

China must also maximise the use of science, technology, and contemporary industrial methods to set a modern agricultural production system, and substantially increase land-use efficiency and labour and agricultural productivity, and reduce postharvest losses. With the development of agricultural science and technology and agricultural education, increased inputs of agricultural capital, technology, and materials (especially in the case of postharvest technology), and the improvement of performance of the market mechanism, the potential agriculture resources will be further tapped.

In the year 2000, the main target for agricultural development was to comprehensively improve the rural economy in order to steadily increase the outputs of the major agricultural products, and to satisfy the desire of the people for a comfortable life and the need to promote the development of the national economy in terms of quantity, variety, and quality. The aim was to increase annual fruit output 54 Mt and to reduce postharvest losses to less than 15%. Fruit output reached the target, but postharvest losses were still more than 15%.

The basic target for agricultural development in the year 2010 is to ensure that the major agricultural products, and products processed from them, satisfy both the needs of a people in transition from a comfortable life to a fairly affluent one, and that for a steady and comprehensive growth of the national economy. The output of fruits will reach 65 Mt and the total losses after harvest will be less than 10–15%.

Although China's agriculture is facing a very arduous task, the reform and opening-up policy to the outside world have created extremely favourable conditions for its development. With the enhancement of the reform and opening-up policy, China's agriculture and rural economy will be even more prosperous. The Chinese Government and people have the confidence and ability to rely on their own strength in solving the problems of food and clothing for domestic residents. China's agriculture will also make a contribution to the development of world agricultural production.

Agricultural Research, Education, Extension, and Cooperation

Following the introduction and development of a market economy in China, the existing agricultural science and research systems are no longer appropriate. The Chinese Government is making efforts to promote the reform of agricultural science and technology. So far, the basics of an agricultural science and research system administered both at central and local levels have been established, and the various agricultural universities and colleges have also built a relatively strong science and research force. According to 1993 data, in the agricultural sector nationwide, there are 1142 state-run independent research institutions. Between 1978 and now, they have won many prizes, and some of them are leading in the world. However, only some of their findings have been put into use. There are 67 agricultural universities and 210 agricultural schools. They have trained many agricultural specialists in China. The Chinese Government attaches great importance to technical and literacy education. By the end of 1994, continued education had been provided to 2.78 million farmers and adults.

China's agricultural extension system was first set up in the 1950s. At present, China has 213,000 agricultural extension units at township level and above. Among them, there are 59,500 extension units for crop farming, but only a few for postharvest of fruits and vegetables.

Up-to-now the Bilateral Agricultural Joint Committees or Joint Working Groups have been set up with more than 20 countries. Meanwhile, ties with major international agricultural organisations and more than 140 countries have been established for the exchange of agricultural science and technology and cooperation.

Summary and Priorities for Postharvest Technologies in China

It is clear that the low quality of fruits and vegetables is a result of poor postharvest facilities, technologies,

and processing practices. China should focus on the following problems of postharvest technologies:

1. Increase the capacity of refrigerated and CA storage for fruits and vegetables and improving the equipment used in storage, such as modern loading machines, transport belts and systems, cleaners, dryers, and elevators and automatic measuring units.
2. Improve the postharvest handling facilities and methods to achieve standardisation, commercialisation, mechanisation, and industrialisation of fruit and vegetable marketing.
3. Computerise the management of storage of fruits and vegetables so as to monitor product quality and ensure smooth distribution.
4. Apply integrated control against fungi, bacteria, and insects to reduce postharvest injury of fruits and vegetables during storage.
5. Improve methods of transport and develop a cold-chain distribution system from production areas to markets for fruits and vegetables.
6. Promote advanced research on postharvest physiology and technology of fruits and vegetables, especially for valuable fruits or new varieties such as Xhonghua peaches, Xinggao pear, jujube fruits, cherry, and some leafy vegetables.
7. Put new techniques of postharvest handling and storage for fruits and vegetables into use and reduce postharvest losses.
8. Establish postharvest technology training courses and a pilot centre to demonstrate postharvest handling treatment to farmers and students.
9. Formulate adequate policies in conjunction with technical measures.

Reference

- Feng, S.Q. 1999. Main postharvest priorities and constraints of postharvest technology in Asia. In: Nawa, Y., Takagi, H., Noguchi, A., and Tsubota, K., ed., *Postharvest technology in Asia. A step forward to stable supply of food products*. JIRCAS International Symposium Series, 7, 25–32.

Postharvest Handling Systems Assessment for Vegetables in China and Australia

John Bagshaw*, Shufang Zheng[†], Xiangyang Wang[§], and Lung Sing Wong*

Abstract

The needs of industry are increasingly being targeted when planning research programs. This is frequently done informally by individual researchers or research groups, but often lacks a comprehensive study of the systems and people in the system. This may result in misdirected, inappropriate, or inadequate research programs that do not meet the needs of the industry groups concerned.

A component of the ACIAR project PHT/1994/016 "Shelf-life extension of leafy vegetables" was the assessment of postharvest handling systems for a range of vegetables in China and Australia.

The assessment methodology selected was an adaptation of 'A commodity systems assessment methodology for program and project identification' developed by J. La Gra of the University of Idaho, USA. We used the methodology in a series of case studies reflecting the main postharvest handling systems. Crops assessed were Chinese cabbage, oriental bunching onion, pak choi (in China), and broccoli (in China and Australia). We assessed:

- fresh and stored, and domestic and export, Chinese cabbage;
- stored oriental bunching onion;
- fresh pak choi; and
- fresh domestic and exported broccoli.

We also included in the assessment peri-urban production and product transported long distances to market.

This paper discusses the methodology used and its advantages and limitations.

THERE is increasing focus on targeting the needs of industry when planning research and development (R&D) programs. This is usually done informally by individual researchers or research groups, but often lacks a comprehensive study of the systems and

people in the system. This may result in R&D programs that do not meet the needs of the industry groups.

A component of ACIAR project PHT/1994/016, 'Shelf-life extension of leafy vegetables', was the assessment of postharvest handling systems for a range of vegetables in China and Australia.

A rigorous assessment of postharvest handling systems provides several benefits to R&D planning:

- it increases the likelihood that R&D outcomes will focus on industry needs;
- it improves adoption of research outcomes because they are more likely to be affordable, practical, and appropriate;

* Queensland Horticulture Institute, Queensland Department of Primary Industries, 80 Meiers Road, Indooroopilly, Queensland 4068, Australia. Email: <BagshaJ@prose.dpi.qld.gov.au>.

[†] Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, People's Republic of China. Email: <zhengshf@btamail.net.cn>.

[§] Department of Food Science and Technique, Hangzhou University of Commerce, 29 Jiao Gong Road, Hangzhou City, Zhejiang Province 310035, People's Republic of China. Email: <wangxyj@mail.hz.zj.cn>.

- it aids understanding of the impact of a technology or practice on the whole handling system. Conversely, it identifies where changes will need to be made in the whole system to accommodate a new practice or technology; and
- it identifies industry trends, allowing R&D focus to change accordingly.

The Methodology

The methodology selected was an adaptation of a more comprehensive systems assessment described by La Gra (1990). The method entailed the following steps:

- *Select case studies*

Case studies representing the main handling systems were identified using a range of criteria. Criteria will differ for each project.

- *Map process flows and document in a process flow chart*

Process flow charts were developed for each system, highlighting every step of the handling and marketing system. The scope of the study was from harvest to retail sale.

- *Describe and document each process in the handling system*

This was done concurrently with the above step. Qualitative and quantitative information was collected by observation, questioning, and measurement, and documented in summary table form.

- *Measure losses where they have been identified as significant*

Where subjective assessment indicated reasonable losses, then actual losses were measured. Losses can vary widely from consignment to consignment depending on weather, season, handling variables, and the people involved. Most of the losses measured were for normal handling conditions.

- *Identify key problems/issues in the handling systems*

Based on data, major loss points and causes of losses were identified.

- *Identify potential solutions, or further R&D required*

After analysing the data collected, the project team identified some potential solutions and future areas of R&D in the handling systems. These included training and extension needs where applicable.

The assessment approach used observation, interviewing, measurement, and qualitative judgment to gather and assess information. Postharvest technology R&D personnel conducted the assessments.

Case Studies

Case studies were selected to represent a range of vegetable postharvest handling systems in China. Studies were conducted in northern China (around Beijing) and central-eastern China (around Zhejiang Province). These are two of the major vegetable production regions in China. Case study selections in these regions were based on crops and season, whether the crop was to be stored or fresh marketed, whether it was for the domestic or the export market, and the distance to market. In addition, one case study was conducted in Queensland, Australia as a model assessment. Table 1 summarises the case studies conducted in this project.

A questionnaire was developed to ensure completeness of information and consistency between case studies. Information generated from these case studies was summarised into tables based on process flow diagrams for ease of analysis. The format of these tables is shown in an appendix to this paper.

Table 1. Postharvest handling assessment case studies.

Crop	Region (season/marketing profile)	Distance to market
Chinese cabbage	Beijing (autumn fresh domestic/export)	180 km
	Beijing (winter stored)	Peri-urban
	Hangzhou (summer/winter fresh)	Peri-urban to 800 km
	Hangzhou (winter stored)	1600 km (Shandong province to Hangzhou)
Broccoli	Beijing (summer fresh domestic/export)	180 km
	Queensland, Australia (winter fresh)	100 km
Oriental bunching onion	Beijing (autumn harvest stored over winter)	80 km
Pak choi	Hangzhou (summer/winter fresh)	Peri-urban to 25 km

Benefits of the Methodology

This methodology was developed to identify, in particular, the technical dimension of vegetable postharvest handling systems, the product losses within the systems, and the causes of losses. From this information, potential improvements and areas of research were identified. Staff from three research organisations conducted the assessments in China and Australia.

During the conduct of the assessments the following benefits became apparent.

- Technical experts can often identify issues and potential practical solutions that may not be recognised by those operating within the system. Outsiders to a handling system can bring a fresh perspective and wider knowledge of opportunities that, when tempered by input from the system participants, can provide very useful ways to improve a system, easily and at low cost.
- Researchers had the opportunity to observe and understand first-hand the whole handling system that their research programs aim to improve. Discussions with farmers, collectors, transporters, wholesalers, and retailers provide an understanding of the handling system from their perspective. Armed with this information, researchers are better equipped to undertake applied research and/or plan effective extension strategies.
- The scope of the assessments was from harvest to retail sale. This provided insights into all parts of the postharvest handling system, rather than focusing on one aspect or one client group within the system. As a result, the methodology enabled more understanding of the impact of a technical or process intervention on the whole system. This in turn highlighted where changes would be needed in the whole system to accommodate new technologies or processes, and who should be targeted in any training or extension programs.
- The methodology identified postharvest handling system linkages. These linkages between the players in the system may be financial or institutional. An understanding of the linkages helps to identify who wields influence in a handling system, and so who to target to bring about effective change.

Limitations of the Methodology

It is important to understand the limitations of any methodology or process so that measures can be taken

to minimise the effects of the limitations, and/or results can be interpreted in context. Limitations of this methodology include the following.

- Some businesses may be unwilling to be studied. There may be various reasons for this. Whatever they are, they must be respected. Approaches to businesses or systems need to be done tactfully, assurances given of confidentiality, and all information collected so treated.
- Because this method relies on a limited series of case studies, there is the danger that they will not adequately represent the range of handling systems within an industry. They need to be selected carefully to ensure most industry circumstances are represented. The number of case studies selected will depend on how well the assessment project is resourced.
- Each case study observes and measures at a point in time. Handling practices and losses may vary from season to season, or even consignment to consignment, depending on weather and market conditions, or any number of other factors. Measures to minimise this problem include conducting case studies during different seasons, targeting those periods of perceived greatest risk (for example, warm, wet, summer conditions in China), and to question people in the handling system about issues, activities, and problems outside the time of the case study.
- Little involvement of industry ‘players’ in determining solutions to problems or determining research needs. In our project, the assessment team (consisting of researchers) conducted this activity. There are many benefits from involving industry in this process including:
 - more complete consideration of practical issues, both technical and non-technical;
 - clearer identification of barriers to adoption of solutions, and so improved strategies for overcoming these barriers; and
 - improved adoption of technologies or processes as a result of more ‘ownership’ by the industry because they have contributed to the final R&D plan. This is more likely to happen if influential industry groups or individuals are involved in the planning phase.
- Our assessments concentrated mainly on the technical aspects of the handling systems, with some unplanned minor assessment of economic, social, and infrastructure issues as participants raised them. La Gra (1990) included these factors in his methodology, but we could not because we had

limited resources and staff. Factoring in this broader analysis with more resources and a more multidisciplinary team could improve the methodology.

Conclusions

The methodology has provided valuable information to the research organisations involved in the ACIAR project and given them a clearer vision for future R&D planning.

A critical step during development of R&D programs is to ensure technologies and processes suggested for improving the handling systems are

practical and appropriate to the infrastructure and resources available to people and organisations within the handling system.

Postharvest handling system assessments need to be linked to robust extension and training programs to ensure improvements are widely adopted by the industry.

Reference

- La Gra, J. 1990. A commodity systems assessment methodology for problem and project identification. Idaho, USA, University of Idaho, College of Agriculture, Postharvest Institute for Perishables.

Appendix

Format of tables used to summarise information gathered during surveys

Table 1. Case study: _____ **Region:** _____

Steps	Action type	Temperature	Distance	Time taken	Observations

Table 2. Case study: _____ **Region:** _____

Steps	Impact of losses (H = High, M = Moderate, L = Low)		Comments
	Quantity	Quality	

Table 3. Case study: _____ **Region:** _____

Step (loss point)	Cause of losses	Suggested solution/further research/ comments

Assessment of Postharvest Handling Systems for Vegetables in Beijing

Shufang Zheng, Wu Li, Lipu Gao, and Ping Wu*

Abstract

The postharvest handling systems for Chinese cabbage, broccoli, and oriental bunching onion were evaluated from harvest to market.

For Chinese cabbage there are three kinds of distribution: fresh, storage, and export. For fresh Chinese cabbage, for which no packaging was applied, losses (about 10–15%) were the result of trimming off old leaves. Pit storage and ventilated storage were used to store Chinese cabbage. Before storage, Chinese cabbage must be trimmed several times and sun-baked to remove excess water. During storage, energy consumption and abscission cause 20–30% loss depending upon the length of storage. No pre-cooling was applied to either fresh or stored Chinese cabbage. Chinese cabbage destined for export has strict handling requirements. First, the product must be trimmed to the degree specified by the purchaser. The cabbages are then pre-cooled in cold room and packed. Trimming before pre-cooling caused losses of 30–45%.

The harvest time for broccoli is usually in the hot season. For the domestic market, no cold chain is available to transport, pre-cool, and store broccoli. Also, the vehicles used to transport the crop provide poor conditions. After more than two hours transportation in hot weather, the quality of broccoli had obviously declined. For export broccoli, on the other hand, every available facility was provided to maintain the commodity, from coldroom through to high quality packaging. However, when coldroom pre-cooling was applied, water loss and efficiency were compromised.

Oriental bunching onion is popular as a spice and fresh vegetable. Harvest time is usually at the end of October. The only packaging used was to wrap the onion bunches in straw sheaves. Bunching onion is not very sensitive to mechanical damage. The main losses after harvest were from water loss and broken leaves. Bunching onion also can be backyard-stored during winter but with high losses. During storage the leaves become dry, but the stem remains fresh with the protection of outer leaves.

For the domestic market, none of the vegetables was provided with good packaging and pre-cooling because these are too costly. For export, all available cold resources were exploited to maintain the quality of produce, though not with any great expertise. At most times in Beijing the humidity is not high (about 40–60%). Thus, vegetables left without protection in the marketplace are inclined to lose water and become unattractive.

VEGETABLES play a very important role in Chinese food. In Beijing, for example, 140–160 kg of vegetables are consumed per capita each year. In contrast with

increases in the vegetable production area and volume, only in recent years has the postharvest handling system attracted the attention of farmers and government. In order to improve and promote new techniques in the postharvest handling system, we conducted assessments of the handling systems for three vegetable crops in the Beijing area: Chinese cabbage, broccoli, and oriental bunching onions.

* Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, People's Republic of China. Email: <zhengshf@btamail.net.cn>.

Assessments

Depending upon crops and production time we conducted the assessments in different production areas and markets. We carried out evaluations in Daxing, Tongxian, and Yanqing counties, which are satellite towns of Beijing, and in Jixian County of Hebei Province, which is a suburb very close to Beijing. Every operation relating to postharvest handling and the losses at each step were recorded and analysed, from harvesting, through pre-cooling, packaging, and transportation, to marketing. At same time, farmers, businessmen, wholesalers, and retailers were interviewed about their operations and their level of skills in post-harvest techniques.

Chinese cabbage

Chinese cabbage is so important to Beijing that it was not until 1995 that the city government released its control on production and distribution of the crop. The production season for Chinese cabbage falls mostly in autumn, between early August and the end of October, but a small amount is also produced during summer. Although a very large area is planted to the crop, no heavy machine is used at any stage from seeding to

harvest. In China, intensive production of vegetables is adopted because of the low area of arable land per capita and the vast labour surplus.

According to its distribution, Chinese cabbage after harvest can be categorised into three groups: cabbage for export; cabbage for the fresh market; and cabbage for storage. The different treatments involved are illustrated in Figure 1.

Process analysis and description for Chinese cabbage

Chinese cabbage for export. Trimming is done twice: first, during harvesting, yellow or rot-infected leaves are removed; and second, at the collection centre, under the guidance of the collector. Damaged leaves are removed before packaging. Most export countries require green leaves (usually four or more) to be removed from the head. Coldroom pre-cooling is used and this causes some water loss. Refrigerated transport is used for export produce. Chinese cabbage is kept at a constant 0–2°C after harvest so losses are low and quality is guaranteed.

Chinese cabbage for storage. Chinese cabbage is stored over winter because crops cannot be grown during this time. Storage begins in early November and may last 4–5 months.

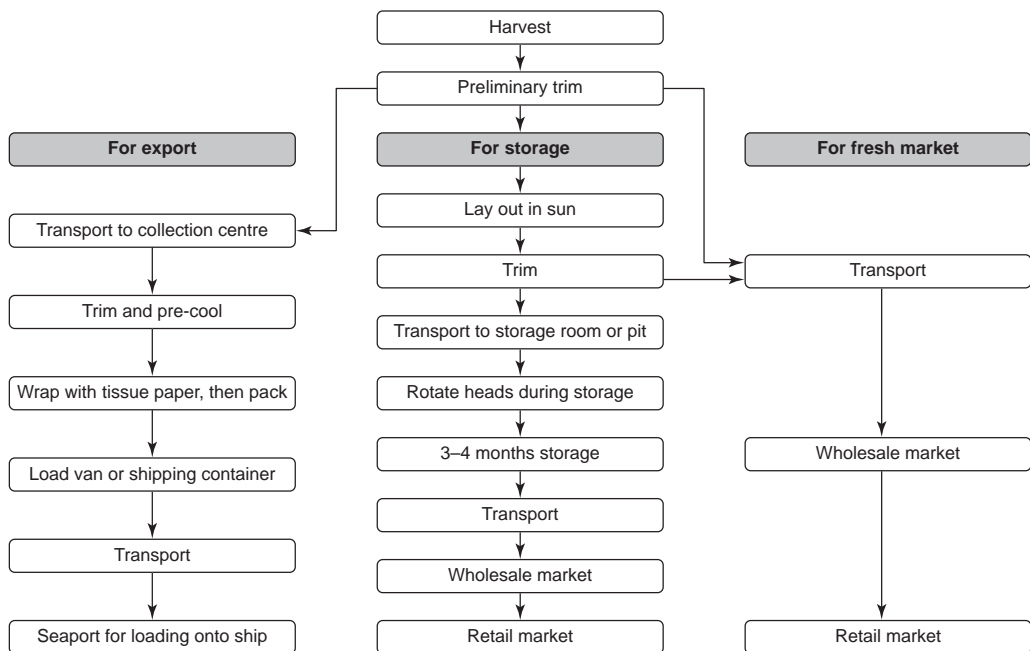


Figure 1. Postharvest process map for Chinese cabbage

During harvesting, yellow or rot-infected leaves are removed. Spreading out the crop in sunlight causes some water loss but hardens the heads to resist disease in storage. Before loading storage pits, leaf tips are removed to reduce rots. During long storage, heads are rotated and trimmed at intervals to remove abscised or yellow leaves. Freezing can sometimes affect heads in storage. During transportation to wholesale or retail markets, mechanical damage and freezing may result in minor losses.

Storage losses are the major loss point for Chinese cabbage and can be reduced by storing in temperature-controlled, ventilated rooms (around Beijing about 10% of Chinese cabbage is stored in this way). Growers who store Chinese cabbage in underground pits can reduce rots and leaf abscission by improving stacking of heads and ventilation of the pits to encourage more air movement around the heads.

Chinese cabbage for the fresh market. Fresh market Chinese cabbage is not pre-cooled or transported using refrigerated trucks. Domestic prices do not justify the use of expensive refrigeration. Most losses are caused by leaf trimming and mechanical damage. The heads of cabbage are trimmed three times: during harvest; at collection centres; and at wholesale markets. Some leaf trimming is essential and some can be avoided. Rough handling and lack of packaging during transport results in mechanical damage.

Good packaging and cold storage would certainly reduce unnecessary losses, but would not be cost-effective for domestic marketing.

Loss measurement of Chinese cabbage

The various handling operations resulted in different percentage losses of commodity, as detailed in Table 1.

Broccoli

Broccoli was introduced into northern China 10 years ago. As a nutritious and high-value crop, it has been widely accepted by farmers and consumers. Because broccoli is very sensitive to water loss and mechanical damage, farmers and businessman take much more care during harvest, packaging, transportation, and marketing of broccoli than they do for other crops. Also, as with Chinese cabbage there are two distribution channels for broccoli: commodity for the domestic market and commodity for export (Figure 2). High quality broccoli is usually segregated for export and handled with care, while lower quality produce destined for the domestic market is handled with much less care in terms of packaging and transportation.

Process analysis and description for broccoli

During harvest and transit to collection centres, there are almost no losses. Minor losses result from loose, infected, and damaged heads (rejected at harvest). Every operation is carried out by hand and with care.

At collection centres, the broccoli heads are sorted into export and domestic quality under the collector's scrutiny. As noted above, higher quality broccoli usually goes to the export market.

Broccoli for export. After sorting, the stems are trimmed to a standard length. Exporters favour compact heads of 20 cm diameter. The heads are then pre-cooled in a coolroom. Water loss of about 1% occurs during pre-cooling, and there is also some minor mechanical damage. A cold chain is used for export commodity. Other operations do not cause losses or damage.

Table 1. Measured losses of Chinese cabbage at various stages after harvest.

Cabbage for export		Cabbage for storage		Cabbage for the fresh market	
Operation	Loss (%)	Operation	Loss (%)	Operation	Loss (%)
Harvesting	5	Harvesting	5	Harvesting	5
Trimming at collection centre	45–50	Spreading out in sunlight	2–3	Trimming	3–5
Pre-cooling and packaging	2–3	Trimming	1–2	Transportation	3–4
		Storage	40–45	Market	5
		Transportation	3–4		
		Market	2–3		

Improved packaging and palletisation would reduce mechanical damage, and might be justified for export broccoli.

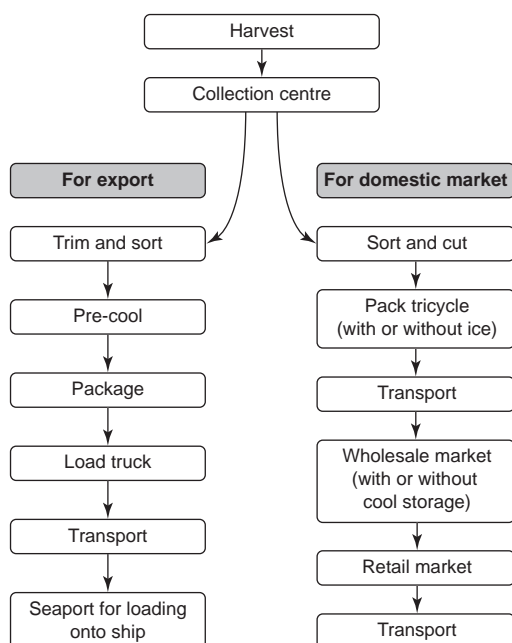


Figure 2. Postharvest process map for broccoli.

Broccoli for the domestic market. Substandard broccoli will be diverted to the domestic market, where even florets are tied together and sold. The main problem for the domestic market is that the cold chain cannot be guaranteed and broccoli suffers heat damage during the time between harvest and retail marketing. The shelf life is only 2 days. Losses occur at collection centres (from rough cutting and handling), during transport, and at wholesale/retail markets where high temperatures leading to rapid deterioration.

Loss measurement of broccoli

Broccoli for export was handled with care so the water loss and mechanical damage were very low. Produce for domestic market, on the other hand, was subject to large losses because of bad treatment and handling (Table 2).

How losses could be reduced

- Use stackable crates for field packing and transport to collection centres

- Handle the product with greater care at collection centres
- Introduce ice or pre-cooling, and insulated bases and covers, during transport to market
- Use cartons for transport and marketing
- Improve conditions at wholesale and retail markets.

Table 2. Measured losses (%) of broccoli at and at various stages after harvest.

Export broccoli		Broccoli for the domestic market	
Operation	Loss	Operation	Loss
Harvest	0	Harvest	0
Trimming and cutting	5–7	Trimming and cutting	10–15
Pre-cooling	1	Transportation	2
Packaging	0	Wholesale market	0.5
Transportation	0	Retail market	2–5

Oriental bunching onion

Bunching onions, one of the important spices in Chinese food, are harvested at about the same time as Chinese cabbage, just before the first frost. The stems of bunching onions are not sensitive to water loss because a protective sheath is formed after the surface dries. At low or freezing temperatures, bunching onions can be stored for 4–5 months, but with high losses because of drying of the leaves. In the Beijing area, bunching onions are usually stored in farmers' courtyards with little cover. The dry winter and spring thus cause massive water loss. Bunching onion is a crop that is treated with minimal care after harvest (Figure 3).

Process analysis and description for oriental bunching onions

Although bunching onions are handled roughly at all stages (dropped, tossed, and trodden on on top of loads), the crop is relatively resistant to mechanical damage. Most losses occur during transportation, storage over winter, and at the wholesale and retail markets.

During loading and transportation some leaves are broken and drop, and heat accumulation during transport stimulates water loss. At market, in order to display produce, it is exposed to sunlight and further loss occurs. Discoloured or wilted leaves are stripped from the stem.

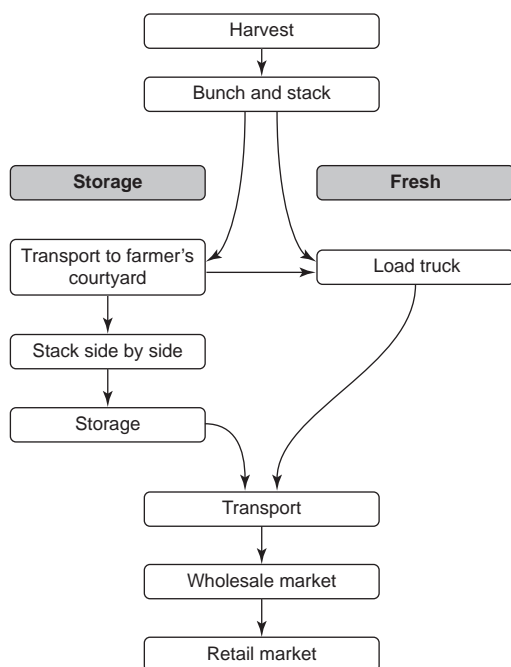


Figure 3. Postharvest process map for oriental bunching onion.

The greatest loss occurs during winter storage when water escapes from leaves and stem skin. Sometimes rot can spread through bunches when they are exposed to rain.

Cool storage and film packaging would be good technical choices for storage, but the low value of bunching onions does not justify the high cost of these technologies at present.

Loss measurement of oriental bunching onions

Water loss is the main cause of the postharvest losses in oriental bunching onions detailed in Table 3.

Table 3. Measured losses (%) of oriental bunching onions at and at various stages after harvest.

Onions for storage		Onions for the fresh market	
Operation	Loss	Operation	Loss
Harvest	0	Harvest	0
Bunching and stacking	0	Bunching and stacking	0
Transit to courtyard	0.5–1	Loading and transportation	5
Storage	45–55		
Wholesale market	0.5	Wholesale market	5
Retail market	0.5	Retail market	2–3

Postharvest Handling Systems Assessment of Pak Choi and Chinese Cabbage in Eastern-central China

Wang Xiangyang* and John S. Bagshaw†

Abstract

Postharvest handling systems for pak choi and Chinese cabbage in eastern-central China were mapped, and losses assessed. The major losses in pak choi handling systems are from mechanical damage, weight loss owing to wilting, and leaf yellowing. The major losses in Chinese cabbage handling systems are from mechanical damage, storage disease (*Erwinia* rot), and weight loss resulting from wilting.

Mechanical damage in pak choi is caused by rough handling when picking into field containers, stacking overfilled containers, washing, and loading onto trucks. Banding at retail markets also causes some mechanical damage. Weight loss occurs during home storage and at retail markets. Leaf yellowing is caused by high temperatures and delays through the handling system.

Chinese cabbage mechanical damage is caused by general rough handling at all stages, but was particularly obvious during weighing and loading of fresh Chinese cabbage at collection centres. The outer leaves are removed by the wholesaler, then the heads are weighed. After weighing, the heads are thrown onto the ground, damaging the newly exposed outside leaves. During loading, loaders walk over produce causing damage. Trucks are overloaded, resulting in pressure damage to heads at the bottom of the load during transport to wholesale markets. Losses from storage rots are caused by storage in poorly ventilated pits under the growing field. Disease problems increase if storage pits are dug in fields with high levels of *Erwinia* rot. Freezing damage during storage contributes to rot development. Rots developing during long-distance transport in wet, warm weather can cause major losses.

Some recommendations for improving handling systems are given in this paper.

A large amount of pak choi (*Brassica rapa* var. *Chinensis*) and Chinese cabbage (*Brassica rapa* 'Pekinensis') is grown in China. Pak choi is an open leafy brassica. It has an inherently short storage life and is usually marketed soon after harvest. Chinese cabbage is a relatively non-perishable crop. It is harvested mainly in winter before freezing temperatures occur and about 10% of the crop is stored for 2–3 months on farms at ambient temperatures in northern China.

Chinese cabbage is not stored in Zhejiang Province, because of the warm winter temperatures there, and cool-room storage is not feasible for this low-priced crop. The handling system for Chinese cabbage is quite different in summer. It is grown in mountain areas, at altitudes above 800 m. It is harvested during hot weather, so losses caused by rotting during transportation can be large (Liu Yisheng 1998).

Methodology

The postharvest handling systems for Chinese cabbage and pak choi in China were assessed to identify limitations to product quality and security, and to make recommendations for system improvement or further targeted research and development. The methodology used was adapted from La Gra (1990) via the

* Department of Food Science and Technique, Hangzhou Institute of Commerce, 29 Jiao Gong Road, Hangzhou City, Zhejiang Province 310035, People's Republic of China. Email: <wangxyj@mail.hz.zj.cn>.

† Queensland Horticulture Institute, Queensland Department of Primary Industries, 80 Meiers Road, Indooroopilly, Queensland 4068, Australia. Email: <Bagshaj@prose.dpi.qld.gov.au>.

following steps: (1) choose case study systems; (2) map process flows for each case study; (3) describe and document each handling system; (4) measure losses; (5) identify problems in handling systems; and (6) present ideas for solution of problems.

Results and Discussion

Pak choi

Process mapping

Figure 1 maps postharvest processes for pak choi in China. Table 1 details losses occurring at each step in the chain.

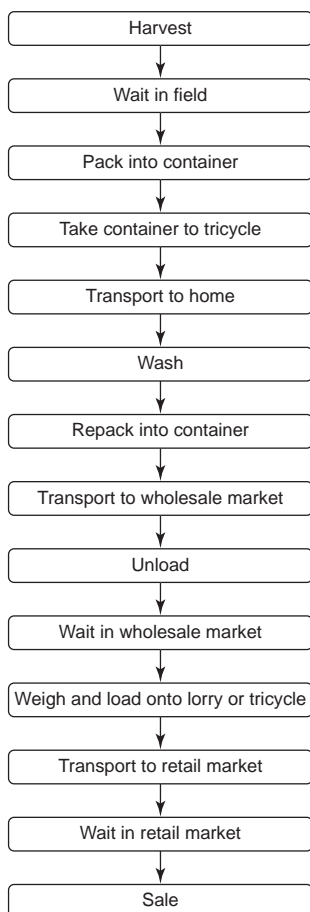


Figure 1. Postharvest process map for pak choi. The crop is harvested in late afternoon (5 to 8 pm) or early morning (2 to 6 am) in summer.

Analysis

The major losses in the pak choi handling system are the result of:

- mechanical damage caused by rough handling when picking into field containers, stacking overfilled containers, washing, and loading onto trucks. Banding at retail markets also causes some mechanical damage;
- weight loss (from wilting) during home storage and at retail markets; and
- leaf yellowing caused by high temperatures and delays through the handling system.

The system could be improved and losses reduced by:

- handling pak choi carefully during harvest and transport to reduce mechanical damage;
- using plastic liners in baskets to minimise abrasion;
- not overfilling containers—use stackable containers for transport (bamboo baskets are largely used; stackable plastic crates are a better option);
- covering the commodity with plastic sheeting while it stands at collection points and wholesale markets;
- reducing waiting times in the system, so as to reduce moisture loss and leaf yellowing;
- retailers spraying clean, cool water over pak choi while it is waiting for sale; and
- avoiding banding at retail markets, or if bands are used make them wide rather than thin.

Chinese cabbage

Figure 2 maps postharvest processes for Chinese cabbage in China. Table 2 details losses occurring at each step in the chain.

Analysis

The major losses in Chinese cabbage handling systems arise from mechanical damage, storage disease losses, and weight losses (from wilting). Mechanical damage is the result of general rough handling at all stages, but was particularly obvious during weighing and loading of fresh Chinese cabbage at collection centres. Outer leaves are removed by the wholesaler, then heads are weighed. After weighing, heads are thrown onto the ground, damaging the newly exposed outer leaves. During loading, loaders walk over produce, causing damage. Trucks were overloaded, resulting in pressure damage to heads at the bottom of the load during transport to the wholesale market.

The occurrence of storage diseases and subsequent losses caused by rotting arise from storage in poorly ventilated pits in the fields where the crops are grown.

Table 1. Measured losses (%) of pak choi at and after harvest.

Season	Area	Distance	Harvest reject ^a	Waiting weight loss ^b	Retail market reject (outer-leaves removed) ^c	Retail market weight loss ^d	Total loss
Winter	Jiangan district	15 km to Hangzhou market	5.7	2.2	21.3 (M=6.4%, Y=7.4, C=5.1, P=2.4)	3.7	27.2
	Xiasha town	25 km to Hangzhou market	8.3	3.5	same as above	3.7	28.87
Summer	Jiangan district	15 km to Hangzhou market	7.7		26.8 (M=8.3, Y=8.2, C=7.1, P=3.2).	7.7	34.5

^a Diseases and pest damage. Undersize plants not included in total loss.

^b At home or at the wholesale market.

^c M = mechanical damage. Y = leaf yellowing. C = sound leaves trimmed by accident. P = pest damage.

^d If sold early in the morning, losses are very small. However, there is no time to trim plants, and untrimmed plants have a lower price. Data at retail level were provided by the retailer.

Table 2. Measured losses (%) of Chinese cabbage at and after harvest.

Season	Area	Distance	Harvest reject ^a	Storage loss ^b	Collecting market loss ^b	Wholesale market loss ^b	Retail market loss ^b	Total loss
Winter	Cixi county	180 km to Hangzhou market	5.7		MD 12.5	MD 15.3	5.5% (MD=4.7%, W=0.8%)	33.3
	Shandong Province	1600 km to Hangzhou market		D 32.7	MD 11.1	MD 0–12.3	5.5% (MD=4.7%, W=0.8%)	49.3 to 61.6
	Xiasha Town	25 km to Hangzhou market	5.0			MD 17.2	5.53% (MD=4.7%, W=0.8%)	22.7
Summer	Fujian Province	800 km to Hangzhou market	6.0		MD 9.3	MD 22.2%, W 3.2	MD=4.3% W=2.0%	41.0

^a Disease and pest damage. Note: undersize plants are not included in total loss.

^b MD = mechanical and disease damage loss (peeled off). W=wilting weight loss. D=disease loss.

Disease problems increased if storage pits were dug in fields with high levels of *Erwinia* rot. Freezing damage during storage also contributed to rot development.

Development of rots during long-distance transport in wet, warm weather can cause major losses.

The handling system could be improved and losses reduced by making the following improvements.

To reduce mechanical damage:

- ensure careful handling at all stages after harvest, in particular after weighing at collection centres;
- trim only at harvest and on arrival at wholesale markets, not on arrival at collection centres;
- during loading and transport, prevent loaders from walking over the produce, and ensure that trucks are not overloaded. Palletisation of bagged heads would reduce mechanical damage but may not be feasible yet; and

- when packing in mesh bags, do not overpack, because the mesh can damage the outer leaves. Some wholesalers wrap heads in paper, then put them in plastic bags, then mesh bags. Plastic bags protect the heads from the mesh and reduce wilting during transport.

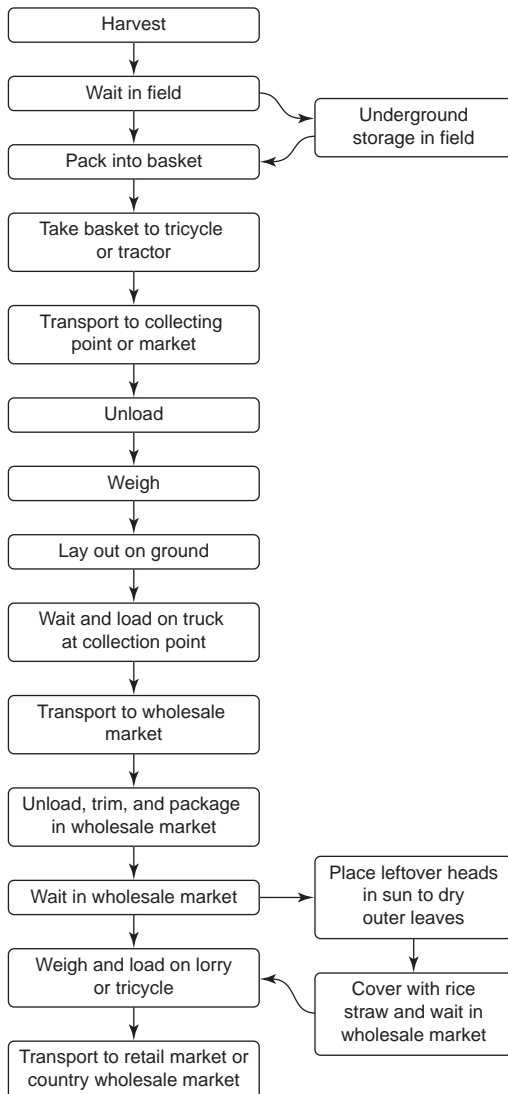


Figure 2. Postharvest process map for Chinese cabbage.

To reduce storage disease/rots:

- do not store the crop in fields with high *Erwinia* rot levels;
- lie the heads in the sun to dry the outer leaves before storage. This provides some protection against rot to inner leaves;
- improve ventilation in pits by cross-stacking heads, and using a lattice platform to stack heads off the ground;
- improve insulation of storage pits to prevent freezing. If using soil, cover with at least 40 cm of soil. It may be able to use other, more efficient insulating materials (perhaps in combination with soil); and
- use ventilated, insulated cool rooms.

To reduce the incidence of rots during long-distance transport in warm, wet conditions:

- pre-cool at collection centres, then cover load with insulating material;
- use cane ‘tubes’ in the load to reduce load heat. One wholesaler was observed using these tubes by placing several through the load, the front of tube outside the load facing forward to catch cool air during night travel, the end of the tube protruding from the back of the load;
- store in cool rooms at collection and wholesale markets during waiting periods; and
- at wholesale markets, lie the heads in the sun to dry the outer leaves if long waits are anticipated. Dried outer leaves provide some protection from rotting to the inner leaves.

Acknowledgments

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References

- Liu Yisheng 1998. Chinese cabbage. China Agriculture Press, 387–412.
- La Gra, J. 1990. A commodity systems assessment methodology for problem and project identification. Idaho, USA, University of Idaho, College of Agriculture, Postharvest Institute for Perishables.

Assessment of the Postharvest Handling System for Broccoli Grown in the Lockyer Valley, Queensland, Australia

Lung Sing Wong* and John Bagshaw†

Abstract

In winter 1999, we assessed the handling system for broccoli grown on a farm in Gatton, Australia and marketed in the Brisbane wholesale market. The assessment covered the chain from harvesting, packing, storage, and transport, through to marketing. Process flow charts were developed, highlighting every step in the handling and marketing system. We gathered information at each process by questioning and observing, and also identified the loss points and hazards to quality. Where possible, we measured loss at each critical point and identified solutions or areas for further research.

The main loss points identified were during harvesting, loading bins for the coolroom, cool storage, broccoli tipped onto carousel sorting tables, and sorting. Potential solutions and areas for further research are discussed.

THE objective of this work was to identify limitations to product quality and security, and make recommendations for system improvement or further targeted research and development. The scope of the assessment was from harvesting to packing, storage, transport, and marketing. We conducted an assessment of fresh broccoli in winter 1999 on a medium-size family farm that markets its broccoli through the Brisbane wholesale market.

- select case study systems;
- map process flows (Figure 1);
- describe and document activities at each process;
- measure losses;
- identify problems in the handling system; and
- present ideas to overcome problems, or for further research and development if required.

The results were tabulated (see Appendix Tables A1–A3).

Methodology

The methodology was adapted from that developed by La Gra (1990), and entailed the following steps:

* Horticulture Postharvest, Queensland Department of Primary Industries, Gatton Research Station, LMB 7, MS 437, Gatton, Queensland 4343, Australia. Email: <wongl@dpi.qld.gov.au>.

† Quality Management Group, Horticulture Institute, Queensland Department of Primary Industries, 80 Meiers Road, Indooroopilly, Queensland 4068, Australia. <BagshaJ@prose.dpi.qld.gov.au>.

Observations

The following observations were made:

- 14% of potential heads were rejected in the field, because of poor shape or colour, small size, damage, or dirt on heads.
- 18% were rejected at packing, because of mechanical damage, dirt on heads (from tractor wheels), over or under-size heads, or misshapen heads.
- Heads were cool-stored for 2–3 weeks at the time of the study (waiting for prices to improve). Most

stems were trimmed at packing to remove cut surfaces that had browned during storage.

- The cool chain was generally well maintained to retail stores.
- Some produce waits at the wholesale market for 4–8 hours overnight at ambient temperatures.

Suggestions for Improvement or Future Research and Development

The following suggestions are made as a result of the assessment:

- At harvest, growers could change from the use of bins on the back of a tractor to a harvest aid with lateral conveyors. Picking staff need to be trained to handle product carefully.
- Damage from tractor wheels might be reduced by wider row spacing of plants or by the use of tractors with narrower wheels.

- Do not over-fill field bins. This will avoid crushing of heads when bins are stacked three-high for coolroom storage.
- Do not store for longer than two weeks (at three weeks, cut stems had turned brown), or identify improved storage conditions to extend storage life.
- Redesign bin-tipping equipment to reduce head damage.
- Train packers to quality standards to reduce the numbers of packable heads being rejected.
- At the wholesale market, store all consignments in coolrooms.

Reference

La Gra, J. 1990. A commodity systems assessment methodology for problem and project identification. Moscow, Idaho, USA, University of Idaho, College of Agriculture, Postharvest Institute for Perishables.

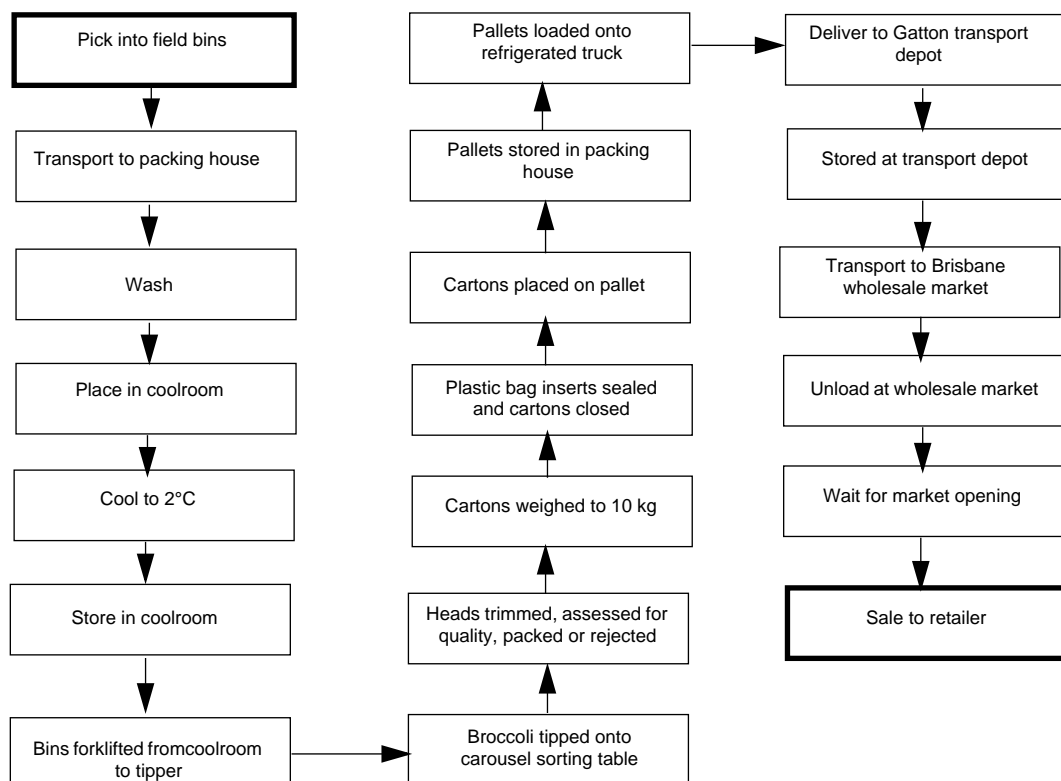


Figure 1. Process flow chart for the postharvest handling system for broccoli grown in the Lockyer Valley, Queensland, Australia

Appendix. Tabulated results of case study assessment.

Table A1. Summary of activities.

Steps	Action type ^a	Temperature	Distance	Time taken	Observations
Pick into field bins	O	Ambient 20–25°C		Time to fill 3 bins 1.25 hrs	Heads cut, leaves near head removed, heads thrown into bin (thrown up to 2 m). Tractor wheels hit heads when soil builds up on wheels
Transport to packing house	T	Ambient	On-farm 1 km Other farms to 10 km	10 to 45 minutes	
Wash	O	Water		5–10 minutes	Water hosed over bins. Aim to cool produce. Inefficient due to water channelling
Place in coolroom	T		Short	Couple of minutes	Use forklift to carry bins
Cool to 2°C	O	Room at 2°C		At least 24 hours	Bins stacked on top of each other in refrigerated coolroom. Room cooled + hose washing to maintain humidity
Stored in coolroom	S	2°C		Up to 3 weeks	
Bins forklifted from coolroom to tipper	T	Product 2°C	Short	0.5–1 minute	Coolroom faces directly into refrigerated 10°C packing area
Broccoli tipped onto carousel table	O	10°C	Short	5 minutes	Small number of heads damaged in tipping. Bin tipped mechanically.
Heads trimmed, assessed for quality, packed or rejected	O/I	10°C		5 minutes per bin	9 packers. Rejects into bulk bin & dumped. Packable head stems trimmed with knife due to browning of cuts after 3 weeks storage. Not pattern packed. Possible damage to heads from adjacent stems
Cartons weighed to 10 kg net	O	10°C			Scales on conveyor line. Regularly calibrated
Bags sealed and cartons closed	O	10°C		30 seconds	Tops of bags twisted and folded then ties with plastic tie. Carton top closed by hand
Cartons placed onto pallet	O	10°C		30 seconds	8 cartons per layer, 5 high, then pallet on top 2 layers high

^a O = operation. T = transport. I = inspection. D = delay. S = storage.

Table A1. Summary of activities (cont'd).

Steps	Action type ^a	Temperature	Distance	Time taken	Observations
Pallet stored in packhouse before transport	S	10°C		1–5 hours	
Pallets loaded onto truck	O	2°C			Forklift. Product probed for temperature and cartons checked for damage by transporter
Deliver to Gatton depot	T	10°C	15 km	Half-hour maximum	Refrigerated truck owned by transporter. Pallets unloaded by forklift. Grower arranges pick up time with transporter
Stored at transport depot	D	2°C		1–4 hours	Stored in coolrooms
Transport to Brisbane wholesale market	T	2°C	100 km	1.5 hours	Refrigerated truck. Arrives between 10 pm and 2 am
Unload at wholesale market	O	10°C		45 minutes	Arrive at wholesale market between 10 pm and 2 am
Wait for market opening	D	10–15°C		4–8 hours	Wait until opening at 6 am. Most produce kept in coolrooms, some at ambient on market floor
Sale to retailer	O	15–20°C			Deliver to retailers coolroom on wholesale market site

^a O = operation. T = transport. I = inspection. D = delay. S = storage.

Table A2. Impact of losses.

Steps	Impact of losses ^a		Comments
	Quantity	Quality	
Pick into field bins	M	M	12–14% rejected at harvest due to poor shape or colour, damaged heads, dirt on heads. Heads thrown into bins sometimes cause damage. Tractor wheels can hit heads, especially if mud builds up on wheels — damage and mud on heads
Stored	L	L	
Transport to packhouse	L	L	Small distance to packhouse from own farm site. On other supplier farms, heads sometimes stored at ambient temperature before transport to packing house
Wash	L	L	Washing process using hose to cool and raise humidity is questionable. Sprinkler set up would be better. Hosing time too short (5 minutes)
Place in coolroom	L	L	Bins placed three high to be forklifted into coolroom. Top bins can crush heads in lower bin. Into coolrooms within half-hour of arrival at packhouse
Cool to 2°C	L	L	Room cooling over at least 24 hours. Heads sprinkled with water regularly to reduce moisture loss once cooled
Stored in coolroom	M	M	If long storage (2–3 weeks), stem cuts may turn brown. Stems need to be trimmed at packing if this happens
Bins forklifted from coolroom to tipper	L	L	Packing area held at 10°C
Broccoli tipped onto carousel table	L–M	L–M	Some loss due to mechanical damage as heads tipped out of bins
Heads trimmed, assessed for quality, packed or rejected	L–M	L–M	Trimmed if stored for a long time. Rejects average 18% (at a time when prices are low). Less rejected when prices are high
Cartons weighed to 10 kg net	L	L	
Bags sealed and cartons closed	L	L	Bags maintain modified atmosphere during marketing

^a H = high. M = moderate. L = low.

Table A2. Impact of losses (continued).

Steps	Impact of losses		Comments
	Quantity	Quality	
Cartons placed onto pallet	L	L	Pallets stacked maximum 5 layers high to meet supermarket requirements (1 pallet × 5 high + 1 pallet × 2 high on top)
Pallet stored in packhouse before transport	L	L	Stored at 10°C for 4–7 hours
Pallets loaded onto truck	L	L	Forklift
Deliver to Gatton depot	L	L	Refrigerated truck at 2°C. Some damage if pallets shift when trucks on rough farm tracks
Stored at transport depot	L	L	Stored in coolrooms
Transport to Brisbane wholesale market	L	L	Refrigerated transport
Unload at wholesale market	L	L	Cool night temperatures
Wait for market opening	L	L	May heat up if held at ambient. Mainly stored in coolroom
Sale to retailer	L	L	Transferred from wholesaler's coolroom to retailer's coolroom

^a H = high. M = moderate. L = low.

Table A3. Problem identification and suggestions for improvement.

Step (loss point)	Cause of losses	Suggested solution/further research/ comments
Pick into field bins	Rejects due to poor shape, colour, damaged or dirty heads. Heads thrown into bins. Tractor wheels hit heads — damage and mud on heads	Variety selection, agronomic improvements. Staff trained to handle product carefully. Use harvest aid (with side conveyor) instead of bins on back of tractor Consider wider spacing for tractor rows, or narrower tractor wheels.
Place bins in coolroom (after washing)	Bins loaded three-high to transfer into coolroom. Top bins can crush heads in lower bins	Do not overfill bins
Store in coolroom	Cut stems turn brown during long storage (three weeks). Need trimming at packing	Avoid long storage
Broccoli tipped onto carousel table	Mechanical damage from contact with equipment	Redesign equipment to reduce damage
Heads trimmed, assessed for quality, packed or rejected	Damaged, undersized, poorly bearded, discoloured, dirty heads rejected by packers	Train packers to quality standards, so packable heads not rejected
Waiting at wholesale market (for market opening)	Some consignments left on market floor. Heat up during waiting	All consignments to be stored in coolroom

Increasing Participation of End Users in Postproduction Research and Development

Robert R. Bakker, Dante B. de Padua, Mark A. Bell, and J.F. Rickman*

Abstract

In the Philippines, the adoption and utilisation of new technologies for postproduction handling of rice have not kept pace with increased volumes of grain, handling requirements for wet harvest, and the growing demands for higher rice quality. To date, the Philippine postproduction sector is characterised by a lack of grain-drying capacity, the presence of antiquated milling systems, and a lack of adequate storage facilities. The current state of affairs can be partly attributed to wrongful targeting of potential users in technology design and development, and a weak collaboration between public and private sectors. Furthermore, agencies involved in research and development have historically approached problems from an inward-looking perspective.

In 1998, the International Rice Research Institute (IRRI) convened a workshop involving representatives of all interest groups in the rice postproduction industry to review the current situation in the Philippines, and to jointly identify priority problems. In response, four national agricultural research organisations and IRRI together identified opportunities for research and launched a collaborative research program to increase the effectiveness of postproduction research in the Philippines. This collaborative program is known as the Philippine Rice Postproduction Consortium and is currently in its third year. The objective of this consortium is to take a more comprehensive approach to rice postproduction research, and increase the participation of technology end users.

A variety of research and development activities is jointly undertaken by consortium members, including in-depth needs assessment studies of producers and consumers, case studies of successful and failed technology introductions, and development of appropriate dissemination strategies for postharvest technologies. In addition, the consortium is in a partnership with the private manufacturing industry to localise production of mechanical dryers in the Philippines.

THE introduction of modern rice varieties to Asia in the 1960s has led to year-round harvest of rice, increasing harvest volumes, and new methods for threshing rice under wet conditions. While farmers have revolutionised rice production, consumers have developed demands for higher quality rice. Modernisation in the postproduction of rice, however, has not firmly taken root. In the Philippines, for instance,

difficulties in rice handling and processing are experienced every year as a result of the continuing lack of drying capacity for wet harvest, and the use of antiquated milling systems. As a result, physical losses occur and the quality of milled rice is poor. The problems are compounded by the growing scarcity of inexpensive labour in agricultural areas, which has accelerated the need for labour-saving postproduction technologies.

The current situation in the Philippines can be attributed to a number of factors. During the 1970s, technologies that were not suitable either for use in humid climates, or for processing high moisture

* Agricultural Engineering Unit, International Rice Research Institute, MCPO Box 3127, 1271 Makati City, Philippines. Email: <r.bakker@cgiar.org>.

grain were introduced from industrialised countries. Moreover, these technologies were based on large capacity, continuous-flow handling of grain and therefore not adjustable to the fragmented delivery of grain that is typical of small farming systems in Asia. In later years, significant investments in grain drying research led to a better understanding of the technical and socio-economic issues involved in crop handling in the region, and the development of smaller, 'appropriate' farm-level drying technologies (de Padua 1988). These activities, however, did not lead to a sustained adoption of more 'efficient' drying technologies by farmers in the Philippines. For example, the acceptance of a low-cost, batch-type grain dryer among Filipino farmers was low (Frio and Manilay 1984). The main reason was that the cost of drying was too high compared with traditional method of drying on pavements; i.e. there was no economic incentive to invest in a dryer. The economic feasibility of farm-level grain drying suffered from the fact that harvest volumes are too small to successfully own and operate the technology. In the 1980s it was recognised that feasibility of mechanical grain drying was more favourable at the cooperative level and, as a result, larger drying and processing systems were installed at farmers' cooperatives. Because of insufficient farmer participation, however, only few cooperative grain-processing facilities are still operational.

In many rice-growing areas of the Philippines, millers and traders have now taken on the responsibility for drying. Selling wet grain forms an intricate part of the agricultural credit system, as many farmers obtain their credit from millers or traders and must sell at harvest. Drying wet grain intended for the consumer market is shifting from farmers to the private, postproduction sector and, as a result, there is a high demand for drying facilities among rice traders and millers. Interestingly, their demand is largely met by imported dryer designs, even though local research and development (R&D) institutions claim that they have developed many designs available for local manufacturing. A survey of rice millers found that none of the locally developed dryer designs met the millers' requirements (de Padua 1999). Apparently, technologies were developed for which there is no real need, at least not in the Philippines.

The unsatisfactory impact of R&D in postproduction technologies in the Philippines suggests a certain confusion as to who are the beneficiaries of the research activities. Historically, smallholder farmers have been the target of R&D undertaken at International and National Agricultural Research Centers. In

handling and processing of grain, however, farmers are increasingly not the key players. As agricultural production has modernised, grain postproduction has gradually moved away from the farm to the postproduction sector, including traders, millers, wholesalers, and retailers. The public sector R&D community has largely disregarded the vital role of the postproduction sector, keeping the sector that handles the bulk of agricultural production away from potential benefits of engineering R&D.

Low R&D impact can also be attributed to a lack of systems-based research. Many engineering research centres are focused largely, if not exclusively, on technology development, with little understanding of the system in which their hardware is supposed to operate. As a result, researchers often operate in an environment that is isolated from the private sector. This impedes the successful commercialisation of the developed technology, as was illustrated by Gomez and Abejuela (1988):

Good researchers are usually poor communicators. Some of the problems in utilisation are caused simply by lack of information about the technology and/or its potential consequences. This may be due to the purposeful isolation of research. Because of this isolation, there is no flow of information from the users to the researchers and vice versa. Researchers are often cloistered in their laboratories, shielded from commercial pressures, and research projects usually produce results that are not directed towards solving problems of commercial significance.

Recognising the need for more demand-responsive, systems-based, and collaborative postproduction research (see also Bell and Dawe 1998), the International Rice Research Institute (IRRI), in association with the primary national research organisations of the Philippines, convened a workshop to determine the priority problems and concerns in the rice postproduction sector. The desired outcome of the workshop was the initiation of a collaborative research program that would increase the efficiency of postproduction R&D by meeting the real needs of the rice industry in the Philippines.

Initial Workshop: Interest Groups Identify Their Roles and Needs

During the initial workshop held at IRRI, representatives of the different interest groups in the rice industry were invited to review the current state of affairs of the Philippine rice postproduction sector, to identify priority problems, and to map out possible responses to

the problems. The workshop also served to draw out interests of different institutions involved in postproduction R&D. The planning and implementation of the workshop was based on a logical framework approach described by Schubert et al. (1991). This methodology involves holding an initial workshop for all stakeholders in the industry, succeeded by a follow-up meeting of research organisations.

Three subsectors of the rice industry were represented at the initial workshop: (1) farmers, farmer groups, and farm service contractors; (2) processors, traders, wholesalers, and retailers; and (3) consumers. In addition, workshop participants included representatives of farm equipment dealers and manufacturers, finance institutions, and government agricultural services. Participants prepared a comprehensive list of problems of, and constraints on, the rice industry. The workshop secretariat sorted the issues into categories based on the subsectors, then analysed the problems further to try to determine their root causes, and to deduce where the research opportunities were. The complete results of this exercise are described in de Padua et al. (2000).

In summary, the farming sector pointed out the scarcity of available information about new and appropriate technology. The information could help farmers produce better quality grain that is preferred by consumers. The difficulties of farmers with small landholdings or farmer groups to acquire expensive postproduction facilities needed to handle harvest during wet seasons were also brought up. The low farm-gate price of paddy caused by the distribution of cheap, imported rice by the government was also raised.

The rice processors and traders cited the low quality of milled rice produced. The low quality could be traced to a variety of reasons, including the lack of good quality seed, the more than 20 rice varieties with different milling characteristics planted by farmers, the poor management of the rice fields, the lack of timeliness in crop harvesting, the inability to handle wet harvest, the poor state of milling machinery, pest infestation of rice in storage, the apparent lack of price incentives to produce better quality rice, and the lack of operator skills and understanding of what it takes to produce higher quality rice. The processors also railed against the rice distribution practice of government, which has upset the pricing of paddy and milled rice, reducing already slim profit margins.

For consumers, mislabeling of rice by retailers was cited. Also, milled rice grades and standards used by the Philippine Government did not reflect what con-

sumers prefer. Consumers look for affordable milled rice with good cooking and eating qualities, and generally prefer white well-milled rice, with few broken and no contaminants.

Equipment manufacturers complained about the lack of incentives to manufacture postproduction machinery in the Philippines. They pointed out that while complete machines can be imported with a low tariff rate, spare parts and raw materials are subject to a higher tariff. Therefore, developing a service industry based on localised production, product support, and supply of spare parts is difficult because of the high price of the raw materials.

In a follow-up meeting, the national research organisations and IRRI further clarified the roles and needs of different interest groups in the postproduction sector, and identified interests and research priorities. Table 1 presents an overview of the identified needs of each interest group. During the follow-up meeting, the researchers felt that a collaborative research program should be inaugurated where the comparative advantage of each institution could be harnessed and a more synergistic project could be undertaken. The five organisations agreed to form a postproduction research consortium that would take on a more comprehensive approach in the research, facilitate better communication of results, and lead to an increase in the participation of technology end-users.

The Philippine Rice Postproduction Consortium

The five principal institutions in the Philippines concerned with rice postproduction research and development participate in the consortium: the Philippine Rice Research Institute (PhilRice), the Department of Agriculture's Bureau of Postharvest Research and Extension (BPRES, formerly known as NAPHIRE), the University of the Philippines Los Baños-College of Engineering and Agro-Industrial Technology (UPLB-CEAT), the National Food Authority (NFA), and IRRI's Agricultural Engineering Unit.

A memorandum of agreement (MOA) was approved and signed by the legal authorities of each institution. The adoption of the MOA by the respective organisations is important as it allows staff members to commit time to consortium activities. In this MOA, it is proposed that the strategic and operational planning of research activities be done jointly by the participating agencies. The consortium meets each quarter to monitor the progress of collaborative projects. Special meetings are arranged by researchers

as necessary, to discuss specific problems such as research methodologies, training curricula etc. The implementation of such activities is realised by using the resources of each collaborating institution, but the consortium is also soliciting government research funds and seeking endorsement of external donors and investors.

Current collaborative research efforts of the consortium concentrate on a variety of different activities. Assessment studies are jointly undertaken in order to validate the technology needs of the different sectors

of the industry as they were identified during the initial workshop. These studies include assessments of milled rice quality in the retail market, consumer preferences for quality rice, and the functionality of current rice standards and grades. Together, consortium members have organised and participated in grain quality training activities for farmer cooperatives and rice millers to enhance knowledge and awareness on factors that affect paddy and milled rice quality. A more formal training course for extension personnel and farmer cooperatives is currently being prepared. It

Table 1. Needs assessment of different stakeholders in production and postproduction systems (in part from Bell and Dawe 1998).

Stakeholder	Needs
<i>Rice farmers</i>	<ol style="list-style-type: none"> 1. Mechanised harvesting technology, competitive with current practices. 2. Guaranteed farm gate prices. 3. Premium prices for good quality paddy harvest. 4. Threshing and transport services to remove burden from farmers, particularly during periods of inclement weather.
<i>Rice processors and traders</i>	<ol style="list-style-type: none"> 1. Local options for upgrading processing plants (specifically: choice of drying plants with the capacity to dry the volumes purchased during the rainy season, with the cost of drying competitive with sun drying). 2. The hardware and software for producing better quality rice products. 3. The technology for utilising rice hull as a source of energy for drying. 4. Milling technology that gives better total and head rice recoveries. 5. Standardised varieties in terms of physical and biochemical properties. 6. Bulk handling technology for lower handling costs. 7. Cost-effective pest control technology.
<i>Extension engineers</i>	<ol style="list-style-type: none"> 1. Information bulletins. 2. Training on postproduction system technologies.
<i>Manufacturers</i>	<ol style="list-style-type: none"> 1. Lower cost of raw material — steel products. 2. Hardware designs. 3. Marketing assistance.
<i>Farmer-based cooperative enterprises</i>	<ol style="list-style-type: none"> 1. Better management skills, both technical and financial. 2. Better procedures, both technical and financial. 3. System designs.
<i>Consumers</i>	<ol style="list-style-type: none"> 1. Graded and packaged rice at reasonable prices. 2. More consistent quality for varietal brands. 3. More choices of products. 4. Longer shelf life of rice products. 5. Less contaminants in milled rice.
<i>Researchers</i>	<ol style="list-style-type: none"> 1. More experience in the commercial processing and business operations. 2. More training on research instrumentation.
<i>Policy makers</i>	<ol style="list-style-type: none"> 1. More economic information. 2. Better understanding of the workings of the industry.

will focus more specifically on how to raise the profitability of rice processing enterprises. Finally, the consortium has launched a public-private partnership with the Metals Industry Association of the Philippines (MIAP) with the goal of manufacturing appropriate mechanical grain drying systems in the Philippines. Activities include joint technology design and adaptation, pilot testing, training of operators, and the organisation of after-sales service. The consortium has recently been granted funding from the Philippine Department of Agriculture for a pilot demonstration at 10 farmers' cooperatives.

Conclusion

The Philippine Rice Postproduction Consortium is currently in its third year, and has produced a number of positive outcomes, including:

1. identification of opportunities to improve R&D agendas in order to better align them with postproduction sector problems;
2. development of collaborative partnerships between interested government parties, who traditionally did not enjoy such close linkages;
3. inclusion of the private sector as a true collaborating partner in public sector R&D;
4. recognition of the private postproduction sector by the government as a legitimate beneficiary of public sector goods; and
5. recognition of knowledge gaps on available postproduction technologies as a major limitation to advances within the sector.

At this stage, the Philippine Rice Postproduction Consortium serves as an example of how research partners can arrive at a list of identified priority oppor-

tunities and jointly plan and implement activities that are relevant to the needs of the industry.

References

- Bell, M.A. and Dawe, D. 1998. Increasing the impact of engineering in agricultural and rural development. Los Baños, Philippines, International Rice Research Institute, IRRI Discussion Paper Series No. 30.
- Frio, A.S. and Manilay, A.A. 1984. Coming to grips with the wet season grain handling problems in Southeast Asia. Proceedings of the 1984 Exchange Program, ASEAN Crops Post-Harvest Programme, Manila, Philippines.
- Gomez, A.A. and Abejuela, A.G. 1988. Commercial utilisation of research results, In: Research and development issues in grain postharvest problems in Asia. Eschborn, Germany, GTZ, GASGA Executive Seminar Series No. 2.
- De Padua, D.P. 1988. Some imperatives in crop drying, In: Research and development issues in grain postharvest problems in Asia. Eschborn, Germany, GTZ, GASGA Executive Seminar Series No. 2.
- De Padua, D.P. 1999. International perspective on local grain post harvest technology. Paper presented at National Grains Post Harvest Workshop, Subic, Philippines, 20-21 May 1999 (unpublished).
- De Padua, D.P., Bell, M.A., Razote, E., and R. Billate, ed., 2000. Philippine rice postproduction systems (PPS) — moving to a brighter future. Proceedings of the workshop held 4-6 November 1998, Los Baños, Philippines, and follow-up meetings 10 December 1998 and 18 February 1999, Makati City (Philippines). Los Baños, Philippines, International Rice Research Institute Limited Proceedings Series No. 4 (2000), 67p.
- Schubert, B., Nagel, U.J., Denning, G.L., and Pingali, P.L. 1991. A logical framework for planning agricultural research programs. Los Baños, Philippines, International Rice Research Institute.

The Postharvest Handling System for Melon in Northwestern China — Status, Problems, and Prospects

Nianlai Chen, Li An, and Keqi Ma*

Abstract

Muskmelon production is an important source of income for farmers in northwestern China, especially those in desert regions. However, the application of postharvest handling techniques to the crop is far from adequate, resulting in substantial losses in quality and quantity of commodity. Weight loss is directly related to diseases promoted by inadequate postharvest treatments. Quality loss is caused primarily by improper handling practices along the chain from harvesting to retailing. Problems exist in almost all procedures. The application of postharvest technology to the handling of fresh fruits and vegetables in China is still underdeveloped. Cost is considered to be the major obstacle preventing the wider utilisation of available postharvest techniques.

In this paper, we overview the present situation, the problems that exist, and the prospects for developing and applying postharvest handling techniques to melons in China, reporting on our research work in ACIAR-supported small project number PHT/1996/152.

In China, muskmelon (*Cucumis melo* L.) crops are divided into two types according to their fruit and properties of their rind (Ma Keqi et al. 2001). One type has larger fruit with a higher sugar content and has rough, thick, and inedible rind. This is called the 'rough-rind muskmelon'. This type includes all crops from three botanical groups or varieties: *reticulatus*, *inodorus*, and *cantaloupensis* (Ma Keqi et al. 2001). The other type, with smaller fruit and thin, edible peel is called the 'thin-peeled muskmelon', and belongs to the botanical varieties *conomons* and/or *makuwa*. What we employed as materials in the small project supported by ACIAR (PHT/1996/152) and discussed in this paper is the first type, which has long been very popular in northwestern China.

Agriculture is still the leading industry in the vast western territory of China. Muskmelon is one of the important cash crops in northwestern China. Approximately 4.0 million tonnes of muskmelon (honeydew, hami melons, and rockmelons) are produced annually in the area, accounting for about 70% of the total in the country. In major production counties and state-owned farms, muskmelon is the main cash crop and may contribute as much as 50% of the income of individual families. It is estimated that, with the improvement of living conditions, market requirements for fresh fruits and vegetables (including melons) will increase dramatically both in volume and varieties sought (Chen Nianlai et al. 2000). Being limited by its small population and relatively underdeveloped economy, northwestern China has to send most of its melon produce to eastern and southern China where the majority of the population and the main melon markets are located. This occurs in the hottest months of a year and transport is over very rough roads.

* Melon Institute, Gansu Agricultural University, Lanzhou 730070, People's Republic of China.

The Present Postharvest Handling System for Melons

Growers are in a positive position in linking to melon markets

As China is now experiencing transformation from a state-planned economy to one that is market-oriented, the marketing system for melon, as for many other agricultural products, is not well developed (Highley and Webb 2001). Most of the muskmelon crop has been planted on small-scale family farms. Each family usually grows only 0.2–0.4 ha of the crop in each season. They have little chance to access melon markets directly. Most farmers therefore program their cropping plan according to last year's experience. They know almost nothing about the coming year's marketing conditions and prices and often commit their fortune at sowing time.

As the harvesting season comes, farmers begin to collect melon price information by visiting nearby communities where the early deals have been made. They make their own judgments on the possible market volume requirement via estimating the number of trucks passing along the main roads near their villages from other provinces or cities. By doing so, they also make their decision on harvesting dates and price requirements. Many melon growers have to take care of other field crops during the melon harvesting season and are frightened by possible economic loss in sending melons to and selling them at remote markets thousands of kilometres away from their home. They wait at the villages until a buyer's truck arrives or may stay by the main road with 2–3 sample melons to attract and 'find' a buyer. The following saying: 'involvement in the perishable produce marketing is risking your fortune' is an expression of the farmers' philosophy about becoming involved in melon marketing. Only a few local young men have the courage to become involved in melon marketing.

When negotiating with buyers, several melon growers might go to a single buyer, eager to sell their produce. They become competitors of each other. They promise low prices and high quality even if they are really unwilling to do so.

Buyers are better positioned in making deals with growers

The buyers, mainly from cities or towns in eastern and southern provinces, usually make their initial decision

on when to buy melons on the basis of melon prices at retail markets and on where to buy on the latest information picked up or past experience. They start their journey, often with a truck, gathering more information of melon quality (primarily fruit size and maturity) and prices as they go, and delay their final decision until the day before buying. Harvesting standards and prices, being negotiated freely between individual grower and buyer, vary from season to season, village to village, and even from case to case, because there are no unified national or local melon standards. Buyers usually go first to the grower's melon field to make a rough assessment of overall melon quality. Then they gave their quality requirements and suggest a price, and discuss those issues with the grower. In such negotiations, the buyer takes advantage of knowing the market price and quality requirements, as well as lack of competition.

Crude harvesting practices and simple handling are common

Only after they have reached agreement with a reliable buyer, or when they are sure through their relatives or friends working or living in other cities that a promised buyer's truck will arrive on the due day, will the growers begin to harvest their crop.

Melons are harvested manually. The activity is labour-intensive and hard work. Growers often ask their relatives and neighbours for help. During harvesting, melons of the maturity and the rough size required by the buyer are cut with scissors by skilled men. They are left with 'T'-shaped stems on and then rolled down to the side furrows (Figure 1). Women and teenagers packed the cut melons into plastic mesh bags. About 35 kg of melons are packed in each bag and, if it is very close, delivered across the field to a collecting spot on women's shoulders. If the melon field is more than 100 metres from open ground (i.e. a suitable collecting spot), melon bags are first delivered to field paths, loaded onto small (3–4-wheel) tractors, several layers stacked up and transported on meandering field paths.

At the collecting point, melons are roughly graded to pick out heavily damaged, under- or over-mature, and under-size fruit (Figure 2). Sometimes, melons in mesh bags delivered from the field are loaded directly onto trucks without grading. They are then weighed, packed again into mesh bags, and/or bulk-loaded onto trucks. A small portion of the melons going to cities in central and southern China may be packed in cartons.

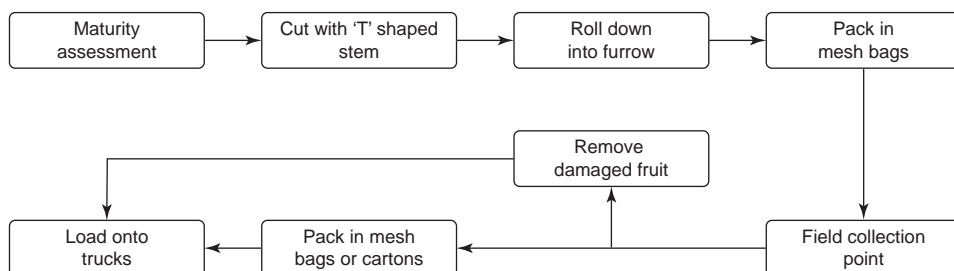


Figure 1. Steps in melon harvesting in northwestern China.

Most melons should start their journey within a day of harvesting, and so are exposed to direct sunlight for only 4–6 hr. But if the buyer's quality requirement(s) are not met so that he refuses to pay, or an expected buyer's truck does not arrive on time, harvested melons might be exposed to sunlight for days, protected only by very simple materials such straw and tree branches or nothing at all (Figure 3). The temperature inside such melons might rise to 45°C.

Transporting and retailing conditions are poor

Long-distance transportation of melons is usually in standard trucks or railway wagons. Only a small proportion (about 1%) is transported in refrigerated trucks or railway cars. Trucks are always overloaded. Trucks with a designed dead-weight capacity of 5 tonnes, for example, often take over 8 tonnes. Retail markets are open, free markets or just pavements along main streets (Figure 4). Melons are exposed to the summer heat and even sunlight during wholesaling and retailing. Such conditions promote quality loss and weight loss through rapid development of diseases.



Figure 2. Grading melons at a field-collecting point.

Major Problems Exist in the Melon Postharvest Handling and Marketing System

The main problems impeding quality preservation and the extensive application of postharvest technology to melons in northwestern China, as we now understand them, are as follows:

Melon growers care little about postharvest quality and quantity losses

Motivation leads to commitment, and commitment is an essential ingredient for the adoption of quality management systems (Bagshaw and Ledger 2000). In the present melon marketing system in northwestern China, most melon growers get their return immediately after their melons are loaded onto a buyer's truck. Whether or not the buyer will eventually make any profit is none of the growers' business. Unless heavy wounding occurs, which reduces their selling volume, farmers neither benefit nor lose from high quality harvest and postharvest treatments. Their ultimate



Figure 3. Melons are often left in the open, exposed to the elements, after harvest.

goal is to increase marketable quantity either by improved yield or lower picking standards. Harvest by stages is a useful method to improve uniform maturity. But farmers regard it as an economically 'harmful' technique, because partly harvested fields usually lose attraction to buyers, and result in yield loss and reduced income for them. The chance that a buyer will come back the next time or in the next season to the same village is so small that it discourages growers from offering high quality melons. So postharvest handling treatments seems to be of no interest to growers. Farmer access to postharvest technology is therefore mainly limited by cost concerns. Harvesting practices are very careless. The traditional practices in harvesting, collecting, and transporting melons include many steps that contribute to postharvest losses, especially those caused by soft rot (infected by *Rhizopus* ssp.) due to mechanical injury (wounds, punctures and bruises) (Shufang Zheng et al. 2000).



Figure 4. Melons for sale at a typical retail market.

Pre-cooling and dipping are almost completely neglected

Pre-cooling can be a very effective way of controlling postharvest losses and maintaining melon quality (Anon. 1980), but cost concerns discourage farmers

from practising any further handling treatments. Dipping is widely used as an efficient disease controlling measure in some developed countries, but is not utilised widely in China.

Packing and grading is simple and needs to be improved

Packing before loading onto trucks has developed gradually in the past decade. Most melons are transported without any packaging or in no more than mesh bags (Table 1). We found in a survey that mesh bags are used by buyers only for their own convenience in handling at markets. Mesh bags cause more damage to melons and are more likely to encourage disease than does bulk freight. Carton packaging was applied to only a small fraction of melons. Grading was performed manually and was very coarse. All it did was remove melons with open wounds and puncture damages, while the majority of the produce with bruises not clear in 1–2 days is kept with good melons. Our investigation showed that reduced mechanical damage either by handling melons carefully during harvesting and delivering or by removing damaged ones before loading to trucks would reduce postharvest losses dramatically (Chen Nianlai et al. 2000).

Poor transporting and selling conditions discount the significance of pre-cooling and dipping

During the long journey of transportation from the west to eastern or southern provinces, the temperature of most melons is not controlled because of a lack of refrigeration on most vehicles. The roads, being poorly covered with a thin layer of tar or simply rocks and sand, are rough and winding. Trucks are often overloaded because buyers want to pay less money for more produce and drivers too mainly earn their profit through overloading. Poor selling conditions also

Table 1. Numbers of trucks travelling to different target markets using various packaging methods.

Packaging method	Target cities			Percentage of total
	Local and nearby	Northern and northeastern China	Central, eastern and southern China	
Bulk freight	101	54	29	31
Mesh bags	103	128	20	42
Cartons	–	44	103	25
Paper-wrapped in cartons	–	2	16	3

diminish the effect of any postharvest handling practices and therefore discourage buyers from implementing them.

A Bright Future Anticipated for Postharvest Handling of Melons

A new supply system has emerged

During 2000, a new marketing system emerged in a few villages in Gansu. It worked as follows. Villagers who grew melons cooperated with local crop collectors to set up a melon collecting ground covered with tent cloth or other shading materials as the melon harvesting season approached. The salesman, together with 2–4 helpers, gathered mature melons at prices according to varieties and fruit size, appearance, and skin colour (maturity index) from individual growers. He then advertised the produce using a large sign across the main road to attract wholesalers from other provinces and districts. Buyers could go direct to this collecting ground rather than farmers' fields to choose the melons they wanted. With such a strategy, farmers benefited from being able to sell their melons at any time they harvested them and could harvest in stages as mature fruit became available therefore increasing their marketable crop. Buyers from distant provinces also benefited from being able to get the desired melons quickly and at more uniform quality. Such a system will favour steady development of melon production and help to improve melon quality, reduce field losses of mature melons, and encourage the application of postharvest handling practices. Melons will be better protected after harvest and heat damage will be reduced.

Pulling force from consumers is expected to develop rapidly

As people's incomes increase, the share of calories they derive from starchy staples declines, while consumption of higher value food increases (Goletti and Samman 2000). These higher value foods include

fresh fruits and vegetables. China is in the final stages of gaining entry to the World Trade Organization, which will mean not only better chances to export its produce to international markets but also stronger competition from imported melons from other countries. Consumers will be more discerning about quality as their living conditions improve and their choices increase. Powerful pull from the markets will drive salesmen and then growers to improve produce quality.

Development of better treatment methods will promote popularisation of the postharvest handling system for melons

To ensure and improve the marketing quality and to extend shelf life and storage duration of melons, better postharvest treatments are required. Progress in developing postharvest handling techniques of melons in northwestern China is already in progress, but much still needs to be done to make it more efficient and readily applicable. Foliar spraying of benzothiadiazole before the blossoming of male flowers has been showed to be an effective potential method in controlling postharvest diseases (Table 2).

Better infrastructure will support the development and utilisation of postharvest handling techniques in melons

Once melon growers or wholesalers are motivated and knowledgeable about quality management systems, their ability to implement these systems depends on the resources they have available. China is now developing its huge western region. Roads linking provinces and counties are being upgraded, and will be much improved in 2–3 years. Even tracks among villages are to be quickly opened. Information services will be strengthened, so farmers can expect to program their planting in more profitable ways. More refrigerated trucks and railway cars will be available for melon transportation.

Table 2. Effect of benzothiadiazole (BTH) foliar spraying on postharvest disease control in melon cv. 'Huanghemi'.

Treatments	Disease incidence (%)				
	<i>Rhizopus</i> rot	<i>Fusarium</i> spot	<i>Alternaria</i> spot	<i>Trichothecium</i> rot	Total
BTH spraying	63	2.48	87	3.03	8.01
CK	5.58*	5.27	8.35**	27.77**	46.97**

Suggestions for Future Work

Preharvest practices should be regarded as an integral part of and essential to quality assurance of melons

More attention should be paid to better cultivars and adaptable growing methods, especially those impinging on melon quality.

Powerful demonstration work is crucial in extending postharvest handling technology for melons

Farmers constitute a very practical group, they show extreme interest and enthusiasm in accepting newly developed techniques as soon as they realise that the methods will bring them benefits. But Chinese farmers are hesitant to apply those new techniques that have not yet shown their usefulness in increasing farmers' income. Even Chinese businessmen are slow to employ advanced practices that have not been firmly established as profitable.

References

Anon. 1980. South China Agricultural University fruit storage and processing. Beijing, China Agriculture Press.

Bagshaw, J.S. and Ledger, S.N. 2000. Quality management systems in Australian vegetable and fruit industries. In: Johnson, G.I., Le Van To, Nguyen Duy Doc, and Webb, M.C., ed., Quality assurance in agricultural produce. Canberra, ACIAR Proceedings No. 100, 439–443.

Chen Nianlai, An Li, and Ma Keqi 2000. Investigation into postharvest loss of cantaloupe. In: Johnson, G.I., Le Van To, Nguyen Duy Doc, and Webb, M.C., ed., Quality assurance in agricultural produce. Canberra, ACIAR Proceedings No. 100, 628–630.

Goletti, F. and Samman, E. 2000. Globalisation and the benefits of a broad-based approach to postharvest systems development. In: Johnson, G.I., Le Van To, Nguyen Duy Doc, and Webb, M.C., ed., Quality assurance in agricultural produce. Canberra, ACIAR Proceedings No. 100, 18–40.

Highley, E. and Webb, M. 2001. Linking farmers to markets. Canberra, ACIAR Postharvest Newsletter No. 56, 6–7.

Ma Keqi, Chen Nianlai, and Wang Ming 2001. The theory and the practices of high quality melon growing. Beijing, China Agriculture Press.

Shufang Zheng, Li Wu, Lipu Gao, and Ping Wu 2000. Assessment of postharvest handling systems of vegetable crops in the Beijing area. In: Johnson, G.I., Le Van To, Nguyen Duy Doc, and Webb, M.C., ed., Quality assurance in agricultural produce. Canberra, ACIAR Proceedings No. 100, 451–455.

Postharvest Handling of Melons in Australia and China

Stephen Morris*, Robyn McConchie†, Keqi Ma§, and Tang Wenhua¶

Abstract

In Australia and China, the main markets for melons are not local, but are in large coastal cities that are often more than 1500 km away from the production areas. In China, there are few interventions to control postharvest diseases or maintain melon quality, and very high losses (up to 35–50%) have been recorded. In Australia, losses are also a problem, but are proportionally lower. The fungicides that have been relied on in the past are either no longer available, or not as effective as they once were. This means that the opportunities to expand local and export markets in both countries are reduced.

ACIAR-supported work aims to improve postharvest disease control, handling, market quality of melons and other cucurbits, and returns to growers in China and Australia. One of the main objectives is to develop strategies for the use of preharvest treatments that boost the natural defence mechanisms in melons, and postharvest treatments to control disease and maintain quality. The work also seeks to develop and test technologies that can be used during storage and transport to improve supply-chain management. The work should promote improvements in the melon industry through the involvement of farmers, marketers, and government agencies and increase the profitability of melon growers in both Australia and China.

MELONS are one of the most important cash crops grown in the northern–central and northwestern provinces of China, with about 80% of the incomes of those farmers growing melons being derived from the melon crop. The production area of melons in the Xinjiang and Gansu provinces increased from 247,570 ha in 1995 to 311,500 ha in 1998. Production during that period increased from 5 Mt to just over 6.5 Mt. The main markets for melons, however, are not local but in the coastal cities such as Beijing, Shanghai, and

Guangzhou, some 1500 km to the east. Prevention of postharvest disease, and maintenance of melon quality during transport, have been major problems for the farmers and wholesalers. Postharvest losses are estimated to be as high as 35–50%.

The Australian cucurbit industry was valued at \$193 million by FAO in 1996. In 1998, it produced about 1 Mt. Watermelons, cantaloupes, and pumpkins make up the bulk of production. Exports during the same period were valued at \$14.2 million, mostly in melons. Australia has developed strong export markets for melons in Hong Kong, Singapore, and New Zealand, and there is potential for substantial further development of markets. However, expansion of the industry is constrained by inadequate attention to fruit maturity, and by postharvest losses and quality deterioration during storage and long-distance transport.

* Sydney Postharvest Laboratory, CSIRO Food Science Australia, PO Box 52, North Ryde, NSW 2113, Australia.

† Department of Crop Science, Woolley Building A20, University of Sydney, NSW 2006, Australia.

§ Melon Institute, Gansu Agricultural University, Lanzhou 730070, People's Republic of China.

¶ Department of Plant Pathology, China Agricultural University, Beijing 100094, People's Republic of China.

The melon industries of China and Australia have similar problems relating to postharvest losses during long-distance transport to central markets located in large cities that are considerable distances from where the melons are produced.

Melon-growing Regions in Australia

There major production areas for cantaloupe/honeydew melons are spread across the country (Figure 1), in temperate, subtropical, and tropical regions. Thus, melons are available on the domestic market all year round. The dry, inland, irrigated areas of South Australia, Victoria, New South Wales, and southern Queensland produce fruit during the warmer or summer part of the year (November–May), and tropical Queensland, the Northern Territory, and Western Australia during the cooler or winter part of the year (June–October).

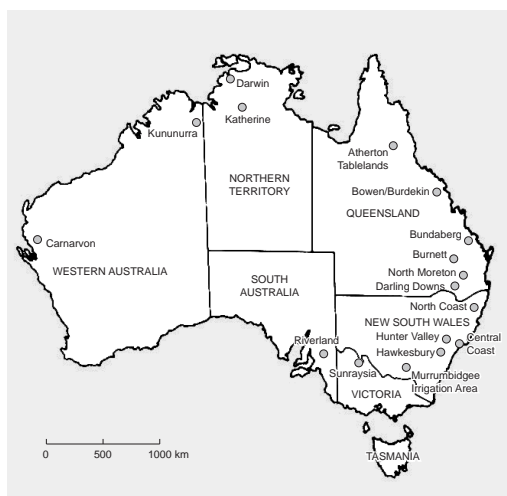


Figure 1. Melon production areas in Australia. Source: Australian Horticultural Corporation Statistics Handbook 1994–95.

Characteristics of Australian Melon Industry

Australian melon producers have large, mechanised, irrigated farms. The melons are harvested in the field by hand or harvesting machine. The fruit are then transported to a packing shed, which is usually on the farm. Farms often have coolroom facilities for pre-

cooling and storage. The washed and packed fruit is transported by large refrigerated trucks to central wholesale markets in capital cities, or directly to the distribution centres of supermarkets chains, also located in capital cities. Transport can take several days and cover thousands of kilometres.

Approximately 20% of the annual production of Australian melons is exported. In 1997–98, 8179 t were exported, with most going to Singapore, Hong Kong, and New Zealand.

An important feature of the Australian industry is that the farmer owns and controls the melons for most of the postharvest and marketing period (Table 1). This means that the farmer can readily implement new technologies and capture the economic benefits from innovations.

Current Constraints to the Australian Melon Industry

The main constraint on the Australian melon industry is postharvest diseases, which reduce shelf life and quality. This is particularly an issue limiting the development of export markets for Australian melons. Another market constraint is that the consumer has no guarantee of fruit maturity or quality. Australia also has a very limited range of melon varieties available and this often means that the flavour and quality of Australian melons is not as high as those in other countries. Unfortunately, except for the State of Queensland, there is a lack of industry organisation and funding, and a poorly focused research effort.

Current Constraints on the Chinese Melon Industry

An important feature of the Chinese melon industry is that the farmer owns and controls the melons for only a very small part of the postharvest and marketing period (Table 1). This means that the farmer cannot readily implement new technologies and capture the economic benefits from these changes. Ownership of the melons during postharvest and marketing is mostly with the wholesalers or ‘businessmen’. It is this group in China that has most control over implementing new technologies and capturing the economic benefits from these changes.

Table 2 compares economic and marketing aspects of the Chinese and Australian melon industries.

Melon Diseases in Australia and China

Fungal fruit rots caused by *Rhizopus* and *Alternaria* species are the major diseases causing postharvest losses in melons. In Australia, control of these diseases is dependent on postharvest treatment with hot-water and dipping in fungicides such as guazatine, and the provision of suitable packaging and storage conditions. However, the treatments do not provide sufficient protection under high disease pressure or during lengthy or adverse transport and storage conditions. In China, few interventions have been made to control postharvest diseases or maintain melon quality, and very high losses are recorded, particularly when

melons are sent over long distances from northwestern China to markets in Beijing and Guangzhou.

With continuing pressure for the withdrawal of post-harvest fungicides (benomyl is already withdrawn) and ongoing problems with quality maintenance, new options are needed to reduce reliance on fungicides to maintain quality during transport and marketing.

Postharvest losses are the result of a complex of diseases present on the melons.

Fusarium rot

Fusarium rot is the major postharvest pathogen. It occurs under most climatic and storage conditions. This is a firm rot that starts on the surface and expands into the flesh. Postharvest fungicides can control the disease.

Table 1. Comparison of melon handling after harvest in Australia and China.

Handling stage	Australia	Owner-ship ^a	China	Owner-ship ^a
Preharvest	Fertilisers, insecticides, fungicides		Fertilisers, insecticides, and (rarely) fungicides	
Farm: Harvest	By hand (skilled pickers)		By hand (skilled pickers)	
Postharvest	Washing, fungicides		Usually none (at buyer's discretion)	
Cooling	Almost universal		None	
Packaging	Cartons and unitised pallets		Minimal (bags or cartons at buyer's discretion)	
Storage	Only short term		Some medium term (at buyer's discretion)	
Transport	Refrigerated trucks Export reefers/planes		Unrefrigerated trucks (refrigerated at buyer's discretion)	
Wholesale	Terminal markets (some directly to customers)		Locally some town markets (interstate directly to customer)	
Retail	Small stores, supermarkets		Almost all small stores, some within work units	




^a  Owned by farmer  Owned by wholesaler  Owned by retailer

Table 2. Overall comparison of Australian and Chinese melon industries.

Factor	Australia	China
Industry value	\$193 million (1998)	\$13.6 billion (1998)
Export value	\$14.2 million	\$84 million
Postharvest losses	Limit exports	35–50%
Markets	Major cities on east coast Expansion constrained by deterioration during transport and storage	Major cities on east coast Major cash crop in west of China Provides 80% of income to farmers

Alternaria rot

Alternaria rot is another very common postharvest rot of melons. This disease occurs mainly on more mature melons after storage. The disease spreads from the leaves and is worse on sunburnt areas of the fruit. It is a surface or very shallow rot that can be controlled by postharvest fungicides.

Rhizopus rot

Rhizopus rot is a particular problem during hot, humid weather. The pathogen enters the melon via wounds or breaks in the skin. This is a soft rot that develops very rapidly. There are currently no good postharvest control treatments for rhizopus rot.

Other postharvest pathogens

Geotrichum soft rot develops very rapidly. It is a problem in high humidity conditions, but there are fungicides available that give reasonable postharvest disease control.

Cladosporium rot develops very slowly. It is a surface rot that develops after cold-storage. It is only poorly controlled by fungicides.

Penicillium rot is another slow-growing surface rot. It occurs after cold storage. Fungicide treatment provides moderate disease control.

Conditions promoting pathogen growth

All postharvest diseases of melons are promoted by high humidity, whether in ambient air or in packaging. Free water or condensation also encourages the development of rots. Fruit that are damaged, sunburnt, or have damage to the skin are most at risk of developing rots. High temperatures and overmaturity are also important factors in the development of postharvest diseases.

ACIAR Project

The objectives of a new ACIAR project currently at an advanced state of planning are to:

- develop preharvest treatments to boost natural disease defence mechanisms;
- develop postharvest strategies for disease control;
- develop strategies to improve supply-chain management;
- make an economic analysis of project benefits and implementation strategies; and

- improve the melon industry through liaison and training of farmers, marketers, and government agencies.

In China, researchers from Xinjiang Agricultural University, Xinjiang Department of Agriculture, Gansu Agricultural University, and China Agricultural University will participate in the work, in partnership with researchers from the University of Sydney, the Sydney Postharvest Laboratory, Food Science Australia, and the Queensland Department of Primary Industries in Australia.

The project will build upon the outcomes and linkages developed in small project PHT/1996/152, 'Postharvest handling and disease control in melons'. Recent research has shown that a range of novel treatments, including use of the strobilurin fungicides and application of chemicals that boost the natural defence mechanisms in plants may reduce disease losses in melons (Hammerschmidt and Yang-Cashman 1995). Pre-flowering foliar applications of acibenzolar-S-methyl (known as BTH or benzothiadiazole) to melons appeared to reduce postharvest losses in trials undertaken in China and Australia as part of the previous ACIAR project. In addition, the postharvest use of the fungicide guazatine alone, or in conjunction with BTH, provided significant control of postharvest diseases of melons in China during transport trials from Xinjiang and Gansu to Beijing.

The new project will carry out further work to assess the efficacy of BTH and other systemic induced elicitors in melons, and to finetune application strategies in relation to environmental stresses such as heat or water-stress. The previous small project also found that there was scope for simple interventions during transport and marketing that would help maintain melon quality and improve returns to growers. However, it was clear that the involvement of farmers, marketers, and policy-makers will be essential if the technology is to be adopted.

The predicted outputs from this project will include a strategy of preharvest treatments involving chemical elicitors and/or fungicides that farmers can use to reduce disease incidence. The project also aims to develop a deeper understanding of the biochemical mechanisms involved in systemically induced resistance (SIR) and systemically acquired resistance (SAR).

It may be possible to develop an effective disease control program involving SIR/SAR and/or fungicides for most pathogens affecting the postharvest quality of melons. An important part of the disease program will

be to understand when to harvest the various varieties of melons to minimise disease problems.

Another predicted outcome is the development of a cost-effective method of packaging and handling that will reduce disease during postharvest storage and protect the commodity during transport. This will be part of developing a supply-chain management strategy to overcome the problems arising from long-distance haulage. Improved supply-chain management by the key stakeholders in melon marketing will help to reduce losses and will provide opportunities to

expand markets. All players in the supply chain will benefit from improved postharvest handling and disease control.

References

- FAO 1996. FAOSTAT Agriculture Database 1996. Internet address <<http://apps.fao.org>>.
- Hammerschmidt, R. and Yang-Cashman, P. 1995. Induced resistance in cucurbits. In: Hammerschmidt, R. and Kuc, J., ed., Induced resistance to disease in plants. Kluwer, 63–85.

West Timor Mandarin Marketing Case Study — Implications for Supply-chain Management in Developing Countries

Sherrie Wei*, Elizabeth Woods*, Damianus Adar†, and Shinta Singgih*

Abstract

Changes in the external environments in food and fibre products in developed countries have brought increased interest in supply-chain management. The global competitive environment is one impetus driving demands for cost-effective food and fibre supply chains. In addition, quality requirements, strict product specification, and food safety issues can be achieved only if food supply chains are transparent and traceable all the way to retail chains. In spite of the interest in developed countries, little supply-chain research has been done in the context of developing countries. This study looks at marketing in the mandarin industry in West Timor, Indonesia and outlines potential participants in supply chains in the industry. With the assistance of non-government organisations, the social constituents of West Timor, like many other developing countries in Asia, can be utilised to foster supply chains, even though their drivers are different from those in developed countries. Traders rather than retailers are often the channel managers and are able to appropriate more values from the chain.

WHILE there has been increased interest in supply-chain management in food and fibre products in developed countries (e.g. Hobbs 1998; van Duren et al. 1998; Westgren 1998), little research has been done in the context of developing countries. This study looks at the marketing system of the mandarin industry in West Timor Indonesia and outlines factors which favour and hinder the development of supply-chain management of agricultural products in West Timor. Much of the discussion in this case study is relevant to other developing countries in Asia that have similar 'natural-social constituents' in the supply of agricultural products (Murdoch 2000).

Supply-chain management refers to the management of the entire set of production, distribution, and marketing processes that deliver competitive products to consumers. In a traditional spot market, business-to-business transactions are decentralised. A producer supplies several wholesalers; a wholesaler purchases from various producers; and likewise retailers have various sources of supply for a given product. Business entities often change their sources of supply and lose and win new customers over time. In a supply-chain environment, the number of actors involved in transactions is reduced and the business-to-business relationship is relatively lasting and more centralised. At one end of the continuum, a supply chain may function close to a situation of vertical integration (for example, the aircraft industry or, to a lesser extent, the automobile industry). In the most streamlined chain, one producer supplies product to one wholesaler, who supplies to one retailer (though the wholesaler may be bypassed). In reality, most chains for agricultural

* School of Natural and Rural Systems Management, University of Queensland, Gatton Campus, Gatton Queensland 4343, Australia.
Email: <s.wei@mailbox.uq.edu.au>.

† Fakultas Pertanian, Universitas Nuas Cendana, Jaan Adisupcitou, Kampus Baru Penfui, Kupang Timor, NTT, Indonesia. Email: <Pdamaianus.adar@eudoramail.com>.

products are loose, fragmented, and unstable over time. A successful chain often has an effective 'channel manager', a role often taken by supermarkets in developed countries. The absence of a channel manager often means the delivery of products is a result of a series of decentralised, dyadic interactions, with no purposeful intention to best serve the end consumers.

Depending on the focus of research interest, supply-chain research may target channel member relationships, information flow among members, and logistical coordination. While these foci are not entirely exclusive, channel member relationships are arguably the most important aspect of the management of the supply chain since good information flow and logistics can better be coordinated once a sound working relationship has developed. This study focuses on channel member relationships in the West Timor mandarin industry. The materials from the case study were obtained during 2000 from interviews with key players in the industry, including producers, traders, government officers, and non-governmental organisations (NGOs).

Background to Supply-chain Management

Supply chains of food and fibre products emerged in developed countries in parallel with a number of inter-related trends and changes in the external environments. Increasing competition has seen horizontal consolidation at the producer, wholesaler, and retailer levels. Advances in telecommunications, transport, and other technologies have enabled competition at a global level, encouraged by declining, albeit slowly, tariff and non-tariff trade barriers. As their lifestyles change, consumers are becoming more particular about quality standards and equitable sources of supply. This demands greater efficiency, transparency, and traceability on the supply of food products. These emerging market requirements have reinforced existing chains by raising entry barriers or by encouraging the formation of new supply chains (Westgren 1998). These new supply chains must not only achieve cost efficiency but also meet quality and traceability requirements in the developed economies.

Properly managed supply chains reduce transaction costs compared with open, spot markets (Williamson 1971), in which transaction costs include product cost, negotiation cost, and information cost associated with continuously finding the best supplier in the open

market. Vertical integration in the marketing chain offers the potential to simplify supply chains through fewer transactions, and reductions in lead times, stock, and waste (Fearné 1994). Alternatively, alliances with other channel members can offer similar benefits to integration while capital costs of integration by acquisition are shared among the partners (Hughes 1994). However, alliances do not necessarily bring about increased profit for the firms or the chain, unless the parties involved have a commitment to interdependence and achieving a shared alliance strategy to create both short- and long-run value (Fearné 1998; Inkpen and Li 1999).

A central issue for supply-chain members is disproportionate appropriation of profits from the value chain. In a competitive marketplace (where there is no distortion such as state protection or related intervention), each channel member performs certain indispensable functions in the chain to deliver the product. Profits for a firm at one level of the chain depend on the relative bargaining power of that firm in two dyadic relationships: one with the channel member one level up the chain and one with the member one level down (Cox 1999). Bargaining power of a firm is contingent upon competition on the same level, availability of substitute products, and the likelihood of alternative supply and outlets.

In developing countries, many of the drivers for food and fibre supply chains in the developed countries are not yet emerging. Businesses are less consolidated horizontally, as there are myriads of unorganised producers, collectors, and retailers. Based on a power perspective, the delivery of goods is a by-product of numerous dyadic negotiations between channel members, and the profit for a business is a reflection of its relative bargaining power with its supplier on the one hand and with its customer on the other. Marketing is likely to be pushed through the chain by suppliers rather than pulled by consumers (Treadgold 1995). Channel members often perform complex rather than specialised channel functions. Farmers can be retailers; first-level collectors may be wholesalers; or collectors can be retailers etc.

Given the infrastructural conditions in most developing countries, such as narrow and poor roads, a lack of cool storage and, in many instances, no telecommunications, the supply of agricultural products is thought to be very efficient because of competition in the open spot market. Farmers in developing countries are often regarded as the weak players relative to their input suppliers and business customers, be it first-level collectors or wholesalers. They are often price takers and not

price negotiators. However, this consequence has to be looked at from a social perspective rather than just from a power perspective. Farmers are often in urgent need of cash owing to lack of business opportunities, planning, and skills. The absence of cool-chain storage in developing countries means they must sell their perishable products at the earliest opportunity after harvest. Alternatively, farmers also enter into forward contracts at very low prices with their business customers. Basically, farmers in many developing countries perform the pure labour function in production. Social structural factors such as their inferior ability in business planning, lack of market knowledge, and the perishability of their products combine to contribute to their weak bargaining position in the supply chain.

Given that making a profit is the primary aim of doing business, it would be unrealistic to expect innovation from within a supply chain to improve information flow and coordination when costs and profits cannot be shared in a satisfactory fashion. In many developing countries, sources of improving the status quo coming from outside the supply chain include international assistance and government aid and training programs designed to lift farmers' knowledge (information and business) to the same level as other channel members.

The West Timor (Indonesia) Mandarin Industry

West Timor is one of the poorest regions in Indonesia and has been targeted by the Indonesian Government and a few NGOs for rural development. Many of the villages in West Timor rely heavily on mandarins as a main source of income. One special variety of mandarin, Keprok Soe (literally 'mandarin from Soe') is grown in West Timor, particularly around Soe Regency. Keprok Soe grows in areas above 800 metres altitude with poor road conditions. Keprok Soe is admired by the local people for its good taste, attractive skin colour (predominantly gold, while most other domestic varieties are green), and relative ease of peeling. Based on its good agronomic performance in West Timor, the Government of Indonesia has promoted Keprok Soe exclusively in West Timor since the 1990s by providing grafted plants of Keprok Soe to farmers. The government uses the strategy of scarcity marketing by not encouraging the growing of other varieties in West Timor and discouraging other regions from growing Keprok Soe. Although the product is relatively scarce, the area has not attracted

exogenous investment owing to poor living conditions and very poor infrastructure.

In the face of competition from imported mandarins in late 1990s, a few traders in West Timor started to sell small quantities of Keprok Soe to more prosperous cities in other islands of Indonesia. Loosely defined supply chains for mandarins have since started to emerge for fruit going to other islands. Their emergence is vastly different from those explanations and drivers offered in developed countries. Mandarin producers are not consolidated or formally organised; there is no obvious increased competition in the industry; and there are no strict specification or traceability requirements in Indonesia.

Other factors have contributed to the development of supply chains in the mandarin industry in West Timor.

Firstly, as in many other developing countries, there are different kinds of informal social groups in Indonesia. Traditional self-help farmer groups still exist in West Timor, whereby farmers of one group help each other in planting and harvesting by sharing equipment and spreading information. Many of the group members go to the same church. Although there is no legal, reciprocal obligation between farmers, behaviour deviating from expected norms would attract a high social cost. These spontaneous farmer groups were not organised for collective action such as to increase the volume of supply, to engage in group selling, or to enhance their bargaining position in relation to collectors. This network of farmers is the 'natural-social' constituent (Murdoch 2000) that has often been useful for interaction between farmers and traders and as a source of mutual learning and innovation. Developing countries appear to have a reservoir of 'relational assets' such as social capital, trust relations, and reciprocity (Storper 1993). All of these have been identified as important aspects favouring supply-chain management in developed countries.

Secondly, the nature of the relationship that exists between traders and farmers is qualitatively different from the dyadic relationship that characterises the channel member relationship in developed countries. Traders and farmers in West Timor know each other relatively well. Traders, based in Kupang (the capital city of West Timor), have informational assets and networking capabilities and are respected by farmers. Because farmers are located remotely from cities and cannot access telecommunications, they cannot take over the functions of traders. Traders also recognise that vertical integration by taking over the production function of farmers is not an option; it is better to try to

assist farmers to produce superior products. In this interdependent relationship, traders feed market information back to farmers, lend money to credible farmers, and assist farmers with harvesting, grading, and packaging techniques under the auspices of NGOs. One trader has an 'open book' policy, showing the margin he gets in the value chain. In the West Timor mandarin industry, there appears a mutual interest for farmers and traders to work cooperatively to improve the production, harvesting, and packaging of Keprok Soe, with a view to selling beyond the local market. What has limited progress is predominantly technical issues of plant protection, an ineffective credit system, and poor infrastructure of roads and transport in the region.

Thirdly, because West Timor is one of the poorest regions in Indonesia, international development funds are available for rural development. For example, the multinationally funded NGO Alpha Omega has been in West Timor since the 1970s. Though its activities are not specifically for the mandarin industry, mandarin farmers are often included for workshops in business skills and general farm-management principles. NGOs and other aid agencies (such as the Australian Centre for International Agricultural Research) often involve farmers and traders as a team to improve the performance of the industry. The presence of these third parties moderates the potentially adversarial relationship between traders and farmers and enhances the already less confrontational relationship.

Unlike developed countries where retailers often control the chain, in developing countries, traders are often the channel managers. In developed countries, because products are pulled by consumers, it is not surprising that the chain member with routine contact with consumers has the greater power. In developing countries, as products are pushed through the channel, the business skills and foresight of traders are crucial to the linkage between farmers and retailers, and consequently the success of a chain. This does not necessarily mean traders are ignorant of consumer preferences. In fact, traders are quite knowledgeable on consumer needs and wants because of the network they have and the relatively homogeneous sensory preference in many developing countries in Asia. In the case of mandarins, fruit with sweeter taste, softer fibre, and gold colour is preferred in some parts of Indonesia (Wei et al. 2001).

In most developing countries, farmers are perhaps the ones who have received least value from the chain, and traders, particularly wholesalers, are often the ones that are able to extract more value. This is partly

because traders often perform the critical functions of channel managers for the chain. Wholesalers often take the initiative to link production and distribution, and to invest in innovations such as branding, packaging, and promotion. Farmers often perform the routine labour function of production.

Discussion and Conclusion

Overall, the West Timor supply chain for mandarins to other islands is an example that is not dissimilar to many industries in developing countries. While there are some ingredients conducive to the development of supply chains, rural economic actors cannot hope to be ahead in relation to international competitors. The challenge for them is to catch up without accentuating the weakness present in the chains of the developed world.

In the West Timor case, there appears to be a mutual interest for farmers and traders to work together to improve the performance of the supply chain. Like many other rural areas in developing countries, West Timor rural areas are dominated by traditional, farm-based economic units, which are integrated with social ties. Consistent with the agrarian traditions, rural areas in West Timor have residual strengths in social norms which are trust-based and emphasise cooperation. Many other developing countries in Asia, such as China, Vietnam, and Thailand, have similar relational assets for collective behaviour once it is properly managed.

Rural development in developing countries is often facilitated by the involvement of third parties such as NGOs. The role of the third parties has largely been ignored by researchers, perhaps because their involvement is project based and short term, and their impact is difficult to assess. Aid agencies can effectively achieve more by targeting not only farmers but also the channel manager in the chain, such as wholesalers in developing countries.

To improve farmer income in developing countries, farmers need to offer more than labour input through innovations resulting in cost reduction, product differentiation, and development. The role of the state and NGOs may focus on the provision of 'soft infrastructure', such as business service provision, training, and knowledge acquisition, and the related capacity-building services (Morgan 1997).

References

- Cox, A. 1999. Power, value and supply chain management. *Supply Chain Management*, 4, 167–176.

- Fearne, A. 1994. Strategic alliances in the European food industry. *European Business Review*, 94(4), 30–36.
- Fearne, A. 1998. Building effective partnerships in the meat supply chain: lessons from the UK. *Canadian Journal of Agricultural Economics*, 46, 491–518.
- Hobbs, J.E. 1998. Innovation and future direction of supply chain management in the Canadian agri-food industry. *Canadian Journal of Agricultural Economics*, 46, 525–537.
- Hughes, D. 1994. *Breaking with tradition. Building partnerships and alliances in the European food industry.* Kent, UK, Wye College Press.
- Inkpen, A.C. and Li, K.Q. 1999. Planning and knowledge gathering for success. *Organizational Dynamics*, 27, 33–46.
- Morgan, K. 1997. The regional animateur: taking stock of the Welsh Development Agency. *Regional and Federal Studies*, 17, 70–94.
- Murdoch, J. 2000. Networks — A new paradigm of rural development? *Journal of Rural Studies*, 16, 407–19.
- Storper, M. 1993. Institutions in the knowledge-based economy. In: *The knowledge economy.* Paris, Organization for Economic Cooperation and Development.
- Treadgold, A. 1995. *Food retailing in South East Asia: Exploiting the opportunities.* Canberra, Rural Industries Research and Development Corporation, Research Paper No. 95/10.
- van Duren, E. and Sparling, D. 1998. Supply chain management and the Canadian agri-food sector. *Canadian Journal of Agricultural Economics*, 46, 479–489.
- Wei, S., Woods, E.J., Adar, D., Maria B., and Serman, N. 2001. Taste panel analysis of mandarin in Indonesia. Paper presented at 11th Annual World Food and Agribusiness Forum and Symposium, 25–28 June 25–28.
- Westgren R.A. 1998. Innovation and future directions of supply chain management in US agri-food. *Canadian Journal of Agricultural Economics*, 46, 519–524.
- Williamson, O.E. 1971. The integration of production: market failure considerations. *American Economic Review*, 61, 112–123.

Industry Trends in Vegetable Production and Marketing in Beijing

Shufang Zheng*

Abstract

Since the early 1980s with economic expansion, vegetable production and marketing has experienced tremendous changes. Before 1985, vegetable production and marketing were controlled and regulated by the city agriculture bureau and vegetable company. After an open policy was adopted, the city vegetable company gave way to free markets at every corner of the city.

In the past, vegetable production was scattered throughout suburban areas around the city, but city expansion expelled production to satellite towns. Nevertheless, production has increased from 3.5 million tonnes in 1990 to 4.89 million tonnes more recently. The types of vegetable grown broadened from about 10 to more than 100. The vegetable production pattern also changed, from small individual farmers with extensive vegetable variety production to loosely connected cooperative arrangements focusing on several kinds of vegetables production. In recent years, the city government has invested in vegetable technique demonstration centres scattered at satellite towns to promote and transfer techniques to farmers. At same time, many companies have invested heavily in vegetable production systems.

As a result of the new, freer production arrangements, Beijing has overcome the poor reputation that it had for restricted availability of vegetables, including the idea that Beijingers had only tasted Chinese cabbage and radishes. Although vegetable production has increased in Beijing, the increase has been insufficient to satisfy market demand, especially in winter (the winter production volume is only about 8.6% that of the full year). This is because of population increase, including large numbers of immigrants. Thus, large quantities of vegetables are transported from neighbouring and southern provinces.

With collapse of the city-controlled wholesale and retail markets, many immigrant farmers have occupied both markets. In the early 1980s they set up booths by the roadside, but they have now moved into sheds with simple facilities. In early 1990s, fresh, high quality vegetables began to be sought by employees in joint venture and foreign companies, so trimmed and packed vegetables began to appear in supermarkets serving people on higher salaries. Then, from 1995 onwards supermarkets mushroomed in urban areas and rising rates of pay enabled ordinary people to buy fresh, clean vegetables off supermarket shelves. Nevertheless, the free markets still account for 70% vegetable trade. No matter whether we consider the free markets or supermarkets, the important thing is that fresh, clean vegetables are now much more readily available than would have been dreamed of ten years ago.

With trade relations with other nations improving, vegetable exports are now part of Beijing's foreign trade. Last year 480,000 tonnes of fresh vegetables were exported to southeastern and other parts of China, and to Japan.

Up to the 1980s, the government controlled vegetable production and marketing in China. A vegetable bureau in the government directed farmers in what and how much they should grow, then a company also controlled by government collected produce from

farmers. There were vegetable shops scattered throughout the city, and these were the only choice for people. But from the 1990s, government control was relaxed and farmers could plan their production and send their produce to free markets. In 1993, control of the last crop, Chinese cabbage, was dropped, and vegetable production and marketing entered a period of free competition.

* Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, China. Email: <zhengshf@btamail.net.cn>.

As open policy and reform were adopted, farmers came to the city and began competing with the vegetable shops owned by government. Because they were not competitive, the vegetable shops collapsed and roadside free markets mushroomed at every corner of the city. Since then, vegetable production and marketing in Beijing have undergone tremendous change.

Trends in Vegetable Production

Vegetable production land retreats to satellite towns

With increasing population and urban expansion, vegetable fields, which were scattered throughout the suburbs in the past, are increasingly moving to satellite towns (Figure 1). In the past, vegetable production around the Third and Fourth Roundroads contributed a large proportion of the vegetables in the Beijing market. Now, however, the fertile vegetable fields have given way to high-rising buildings and freeways. Satellite cities and towns, such as Tongzhou district, Daxing County, Yanqing County, and Shunyi County, have become the main vegetable production areas. From 1995 to 1999 the total vegetable fields of those four production areas increased by over 12%, from 53,785 to 60,462 ha, while suburban vegetable field fell by 26% from 16,146 to 11,933 ha.

Vegetable production areas and volumes are up

Along with increasing demand and improvement in living standards the vegetable production areas and volumes are expanding. In 1990, the per capita consumption of vegetables was 80–100 kg/year. By 1998 this had risen to 160 kg. Also, because of large-scale immigration of rural people, company employees, and tourists, the market demand has surged. Statistics show that there are 13.8 million people plus 3 million immigrants from other parts of China in Beijing in 2001.

The area of land devoted to vegetable growing rose to 93,517 ha in 1999 from 90,882 hectares in 1995 (Figure 2), while production rose to 4.89 Mt in 1999 from 3.97 Mt in 1995 (Figure 3).

More varieties of vegetables are now grown and consumed

In the 1980s, only tomato, cucumber, eggplant, pepper, and spinach were available during summer

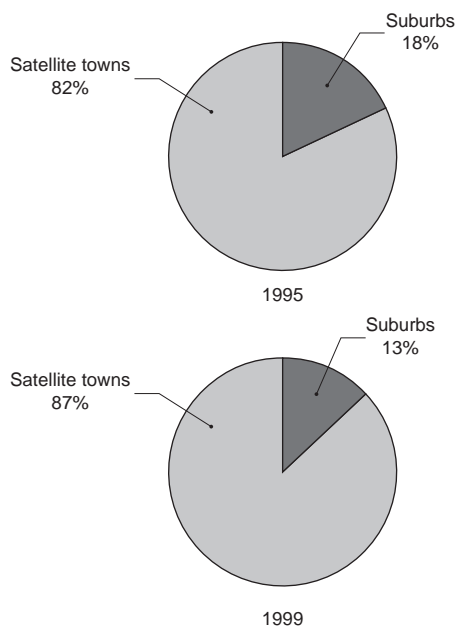


Figure 1. The shift of vegetable production land from suburban areas of Beijing to satellite towns.

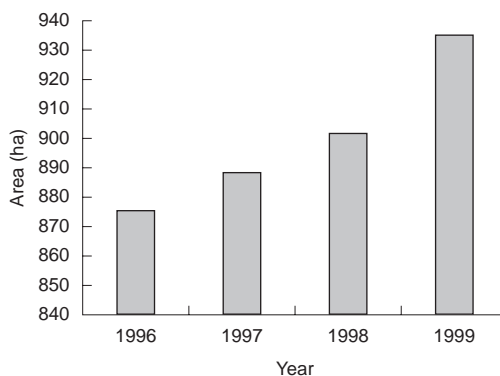


Figure 2. The growth in area of land devoted to vegetable production around Beijing, 1996–1999.

and autumn, while radish, potato, and Chinese cabbage were all that was available for all of winter and spring. Now more than 100 varieties are planted and some can be grown all year around as a result of greenhouse production. The nightmare that in winter only radish, potato, and Chinese cabbage would be available has disappeared.

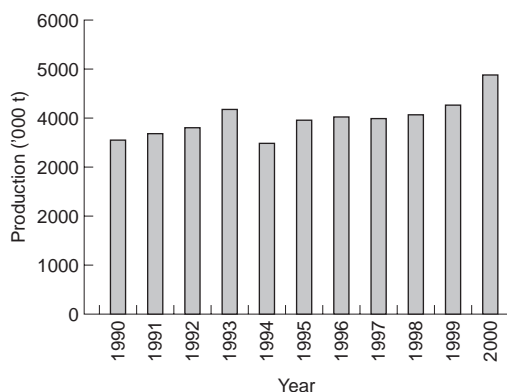


Figure 3. Volume vegetable production in Beijing, 1990–2000.

More greenhouses have been built to produce vegetables in winter

To meet market demand in winter, more and more greenhouses, most without heating, are being built. Greenhouse area was 10,000 ha in 1999, producing almost 1 Mt of vegetables.

Vegetable production pattern is transformed

Vegetable production in Beijing is dominated by small, individual farmers, with each farmer toiling on a small patch of land. However, one kind of loose cooperative association has been formed, whose members concentrate vegetable land and specialise their production to 2–3 kinds of vegetable crops. Although the government abandoned its control on vegetable production, it now spends more on setting up vegetable production gardens to demonstrate and transfer new techniques to farmers. There are more than 10 such demonstration gardens around the city. Some farms in the suburbs function not only as vegetable production areas but also attract sightseers.

‘No harm vegetables to health’ policy is advocated and adopted

As they become aware of environmental pollution, people are shifting their choice to ‘green vegetables’, which are produced without or with reduced amounts of pesticides and fertilisers. In order to reinforce the policy, the government has set up inspection groups in wholesale markets to monitor vegetables. The Beijing Vegetable Research Center cooperates with govern-

ment to advocate and demonstrate new techniques to farmers to help them produce safer and fresher vegetables. More and more farmer cooperatives are applying for the ‘Green Food’ brand to upgrade their produce.

Trends in Vegetable Marketing

Free markets dominate vegetable market

Since the collapse of the vegetable shops owned by the government, immigrant farmers fill the vegetable markets. Hard work and endurance are essential for vegetable retailers and wholesalers and few urban people are willing to accept such a life. Now all the roadside free markets have been closed and their stallholders moved into shelter markets. The free markets are usually built and managed by communities.

In the past, ordinary people could not buy vegetables in supermarkets either because none were available there, or if they were they were unaffordable, except to foreigners and employees in joint ventures. Now there are more and more supermarkets in which people can buy clean and cheap vegetables.

Wholesale markets with responsibility for vegetable distribution

There are about 10 large vegetable wholesale markets serving as vegetable distribution centres scattered around the city. Wholesale markets provide places for wholesalers and retailers to do business. Conditions at most wholesale markets are very basic; some deals are made on the open floor, and sometimes sheltered areas are available. There are few cold-storage rooms and advanced facilities in the markets.

Conditions in wholesale and retail markets

The ambient relative humidity in Beijing is usually very low, presenting the greatest disadvantage to vegetable shelf life. In the wholesale and retail markets, most vegetables are not packed properly. More seriously, there is no cold chain available and this is essential to vegetable shelf life, especially in the hot season.

Vegetables from other areas play an important role

In 1999, 1.2 Mt, about 25% of total vegetables in the Beijing market, came from other areas. The sources of these vegetables change with the production season. In winter and early spring, most vegetables imported into

Beijing are from southern China; in spring they are from neighbouring provinces, such as Shandong, which is a major vegetable production area. In summer the source shifts to northern China. The range of sources of vegetables make Beijing a large market in which fresh, diverse vegetables are available year around.

More and more people make the supermarket their choice

With more and more supermarkets opening near communities, people like to go to them to buy vegetables that are clean, fresh, and well packed, and sometimes

cheaper than those in the free market. At present 10–15% vegetables are sold in supermarkets.

Export becomes a favoured choice of vegetable farmers

Because of low labour costs and cheap land, the vegetable export industry has boomed in recent years. Japan, South Korea, and South Asia have become major vegetable export markets, though South Korea and Japan have imposed restrictions on Chinese vegetable imports. In 1999, about 480,000 t of vegetables were exported. Vegetables exported from Beijing include broccoli, Chinese cabbage, snow pea, cabbage, and tomato.

Trends in China's Vegetable Exports

Wu Li*

Abstract

China is the world's biggest vegetable producer. Some 13 million ha are devoted to vegetable production, which totalled 405 Mt in 2000. The land produced an average of 300 kg of fresh vegetables for each citizen. China grows a wide variety of vegetables and their cultivation has been rapidly developing in recent years.

There has been a strong trend in exports of vegetables by China since 1990. Statistics for 2000 from vegetable production areas indicated exports totalling 3.15 Mt. The provinces of Shandong, Jiangsu, Zhejiang, Fujian, Guangdong, Liaoning, Heilongjiang, and Gansu, and the cities Beijing, Tianjin, and Shanghai are 11 of China's largest source regions for vegetables for export.

Chinese cabbage, cabbage, radish, garlic, onion, oriental bunching onions, beans, broccoli, Chinese broccoli and choy sun, carrots, ginger, and Chinese yam are the main fresh vegetables exported. Beans and potatoes are the main frozen vegetables exported.

Vegetables have been exported to Japan, South Korea, Singapore, Malaysia, Russia, Canada, and Europe.

The trend to increasing exports of vegetables by China has raised postharvest problems in the areas of, for example, pre-cooling, packaging and transport.

THERE were only a few varieties of vegetables available for export in 1978 owing to production and circulation reasons. They included dehydrated mushrooms, boiled bamboo shoots, and so on. Vegetable exports saw a rapid increase after 1990, with the establishment of vegetable bases at different places (Tang Yan 2000). Table 1 details amounts and values of exports between 1992 and 2000.

Types of Vegetables Exported

The main types of vegetables exported include the following:

- frozen vegetables such as peas, beans, potato, and spinach;
- salted vegetables such as turnip and cucumber;

* Beijing Vegetable Research Center, PO Box 2443, Beijing, People's Republic of China.
Email: <liwu@public.bta.net.cn>.

- dehydrated vegetables such as mushrooms and other edible fungi;
- fresh vegetables such as Chinese cabbage, rutabaga, winter white, broccoli, Dutch beans, garlic sprouts, carrots, and onions; and
- fresh processed vegetables such as Chinese yam, taro, green Chinese onion, and garlic. Exports of fresh and processed fresh vegetables have increased rapidly in recent years. In 1999, 59.5% of total vegetable exports were of fresh and processed fresh vegetables.

Main Vegetable Importing Countries

China's main export markets are in Japan, South Korea, Russia, Singapore, Malaysia, the European Union countries, and the Hong Kong Special Administrative Zone of China. In 1999, 74.5% of total vegetable exports went to the Japan, South Korea, Russia, Singapore, and Hong Kong markets. Exports to Japan

amounted to 880,000 t, which made up 40.4% of the total.

Main Vegetable Exporting Provinces and Cities

China's main vegetable exporting provinces and cities are located in coastal areas and in inland areas with favourable production conditions. They include the following provinces—Shandong, Fujian, Zhejiang, Guangdong, Liaoning, Heilongjiang, Anhui, Gansu, and Jiangsu, and the Inner Mongolia and Xinjiang Autonomous Regions. The provinces that export the largest amounts are Shandong, Fujian, Zhejiang, and Guangdong.

Table 1. Vegetable exports from China, 1992–2000.

Year	Amount (Mt)	Value (US\$ million)
1992	1.06	790
1993	1.40	950
1994	1.54	1250
1995	2.40	1710
1996	1.67	1530
1998	1.96	na ^a
1999	2.18	na
2000	3.15	na

^a na = data not available

Export Enterprises

Enterprises engaged in vegetable exports have been developing rapidly, with more joint ventures being set up. Cooperative partners are mainly from Japan and Korea. With the growth of export activities, export enterprises are setting up relatively modern vegetable processing plants and cold stores for keeping produce fresh.

Construction of Vegetable Centres for Exports

Various provinces and cities have established a number of export-oriented and relatively stable vegetable production centres to take advantage of local natural advantages. Representative examples are: Shouguang, Laiying, and Anqiu in Shandong prov-

ince; Xiamen and Zhangzhou in Fujian province; Dongguan, Shantou, and Zhuhai in Guangdong province; Wenzhou, Ningbo, and Hangzhou in Zhejiang province; Dalian and Dandong in Liaoning province; and Yanqing and Daxing in Beijing. Various centres often conduct technical training on matters such as the improvement of productivity of export products, prevention and control of pests and diseases, and means of reducing the application volumes of farm chemicals.

Administration of Vegetable Exporting

State inspection and quarantine departments have enacted industrial standards and inspection regulations covering the export of different varieties of vegetables (Gong Junqiu 2000). These departments apply strict quality control to export vegetables, taking heed of relevant stipulations of importing countries on vegetable product quality. Strict tests are also applied for microorganisms and chemical residues to comply with the requirements of those responsible for the establishment of the quality control system in vegetable production centres and the exporting enterprises.

Current Problems in Vegetable Exports

China's vegetable exports are growing quickly, and several problems need to be resolved.

1. Owing to the adoption of traditional cultivation methods, the rates of commodity available that meet export standards are low.
2. Export enterprises are small scale, resulting in low efficiency.
3. The quality of vegetables offered for export is not consistent, and the market competitiveness is low.
4. International markets are over-concentrated, and are easily affected by importing countries' markets and policies.
5. Facilities for postharvest processing are scarce; processing facilities and technologies are backward.

Prospects for Vegetable Exports

China is a large country with a wide range of climates. Vegetables are produced all year round. Some remote areas are very suitable for the production of green vegetables, organic vegetables, and forest vegetables, which are fashionable in the international market. The

cost of vegetable production in China is much lower than in developed countries. All of these factors have provided solid conditions for growth in vegetable exports. Furthermore, China will enter the World Trade Organization in the near future. This will be a good opportunity for Chinese vegetables to penetrate international markets.

References

- Gong Junqiu 2000. Export vegetable quality control. Shandong Science and Technology Publishing House.
- Tang Yan 2000. Trends in exporting vegetables and importing vegetables in China. *World Agriculture*, 9, 58–59.

Australian Studies on Storage and Packaging of Asian Leafy Vegetables, Chinese Waterchestnut, and Kabocha Pumpkin

Graeme Thomson*, Sonja Winkler*, Wendy Morgan*, David J. Midmore†, Volker Kleinhenz§, Geoff Lodge¶, and Bruce Tomkins*

Abstract

Recent investment in postharvest research programs has provided substantial improvements in the quality and supply of Asian vegetables in Australia. Development of product descriptors, and optimum postharvest handling and packaging protocols, have improved quality and reduced wastage. Crops like pak choi (*Brassica rapa* var. *chinensis*) and gai lum (*Brassica oleracea* var. *alboglabra*) are now a permanent part of the vegetables on offer at mainstream supermarkets throughout Australia.

Modified atmosphere (MA) packaging has been developed for many Asian leafy vegetables and herbs in conjunction with the investigation of appropriate cool storage temperatures to maintain quality and avoid chilling injuries. Quality following storage of 11 leafy Asian vegetables was demonstrated to be better from MA packaging than from 'high humidity' packaging that maintained an air atmosphere. Atmospheres high in CO₂ and low in O₂ generally helped to reduce leaf yellowing and the proliferation of rots.

Research to optimise postharvest quality has also extended to biochemical analysis. Six varieties of 'Kabocha' pumpkins (*Cucurbita maxima* × *C. moschata*) grown for export to Japan were analysed for sugar content and carotenoid levels to help select product that best met market requirements. The colour of the flesh was also considered along with skin colour and skin blemishes.

The Australian market demands quality Chinese waterchestnuts (*Eleocharis dulcis*) with a high level of sweetness in association with plump, crisp, and turgid corms. To minimise weight loss in stored corms and to promote sweetness, different packaging materials, storage temperatures, and storage durations were investigated. Over a 5-month storage period at either 1 or 9°C, weight loss of corms was acceptably low (i.e. less than 10%) if stored in either snap-lock bags made of low density polyethylene (LDPE) film, or 'Longlife' vegetable bags (microperforated LDPE film). Higher storage temperatures were associated with a decrease in sugar content and increase in sprouting.

A wide range of Asian vegetables has been available in Asian grocery outlets in Australia for many years. In more recent times, Australian horticulture has seen an increased focus on the growing of vegetables that are

Asian in their origins. The increase in popularity of these vegetables is now reflected at mainstream supermarket outlets where a range of Australian-grown Asian vegetables is now available in our capital cities. However, there is still potential to increase the range and quality of Asian vegetables in supermarkets, greengrocers stores, and restaurants. Our producers of Asian vegetables are now looking to market Asian vegetables in neighbouring Asian countries where Australian produce has a reputation for quality.

However, the fragmented nature of the 'fledgling' Asian vegetable industry presents specific problems with respect to supplying markets with high quality

* Institute for Horticultural Development, Agriculture Victoria, Knoxfield, Private Bag 15, Scoresby Business Centre, Victoria 3176, Australia.

† Central Queensland University, Plant Sciences Group, Rockhampton, Queensland 4702, Australia.

§ Srinuan Court 113, 147–149 Sukhumvit Road, Soi 22 Prakanong, Bangkok 10110, Thailand.

¶ Eco-lodge-ic, 380 River Road, Murchison North, Victoria 3610, Australia.

produce. Primary growing areas are scattered throughout the eastern seaboard, and while this provides opportunities for diversity and extended supply, the logistics of sourcing and transport are made more complex. Many popular Asian vegetables are leafy and fragile, and therefore require careful handling and transport to ensure that consumers have access to a product in top condition.

Good postharvest management can deliver horticultural produce to the end consumer in a condition which is virtually unchanged from harvest time. Handling should avoid mechanical injuries, preserve the product's food reserves and storage life, restrict water loss, and avoid proliferation of microorganisms. By increasing the use of best postharvest practices in the Asian vegetable growing industry, profits can be increased through improved quality and reduced waste.

Modified Atmosphere Packaging for Selected Leafy Asian Vegetables and Herbs

Modified atmosphere (MA) packaging uses the plant product's natural respiration to create a high carbon dioxide, low oxygen atmosphere which extends the life of stored produce. The packages provide an improved storage environment for herbs and vegetables during distribution, thereby ensuring high product quality for consumers.

This research was started in conjunction with a commercial packaging manufacturer, but it became obvious that the relatively small needs of the Asian vegetable industry in Australia would mean low-volume manufacturing and high costs per bag. Consequently, packaging was sought that could be bought 'off-the-shelf', enabling better accessibility and pricing for growers. At manufacture, these bags were not intended for use with Asian vegetables but through testing of product types, storage temperatures, sizes, and film permeabilities, bag specifications were matched to the needs of different product types. Design of any particular MA package depends on:

- the crop for which it is intended;
- the respiration rate of that crop at the required handling/storage temperature;
- the amount of crop to be stored; and
- the properties of the film used for the package.

Respiration rates of each product were measured at a range of temperatures before selection of packaging, and again in conjunction with packaging trials.

New MA bags were tested for snake beans, hot chillies, perilla, Thai basil, coriander, spearmint, hot mint, Chinese garlic chives, pak choi (= Chinese chard), baby pak choi, kai choi (= mustard green, Chinese mustard), kangkong (= water convolvulus), and amaranth (= Chinese spinach) (Table 1). The bags were prepared for use at temperatures close to each crop's optimum storage temperature. For chilling sensitive products such as Thai basil, snake beans, and kangkong, this is approximately 12°C, while for the other crops the optimal storage temperature is typically between 0 and 4°C.

Package sizes were governed by industry requirements and constraints: perilla, 3 bunches; snake beans, 100 g; baby pak choi, 12 bunches; kai choi, 12 bunches; kangkong, 12 bunches; and hot chilli, 100 g. Five-bunch MA packages were developed for spearmint, hot mint, Thai basil, pak choi, and Chinese garlic chives.

Performance of the new MA bags was compared with that of the 'high humidity' bags currently used by some industry sectors. High humidity bags restrict some water loss but they do not restrict the movement of carbon dioxide or oxygen through the film so the atmosphere surrounding the produce is very close to normal air.

Packaging for perilla

The process of package development for perilla (*Perilla frutescens*) is documented here. Similar procedures were used in formulating the package specifications listed in Table 1. Packaging trials for perilla examined the performance of three types of plastic packaging at two storage temperatures (0°C and 4°C), followed by a simulated marketing period at 8°C. Two types of bag designed to give a modified atmosphere were compared with a control 'high humidity' bag.

Bag details (dimensions were 250 × 330 mm):

- Control, high relative humidity bag. A 50 µm thick polypropylene clipseal bag perforated with two holes of 5 mm diameter.
- MA1, 50 µm thick polypropylene bag. (Film specification: ICI propafilm, biaxially orientated polypropylene (BOPP) ML50 with an oxygen transmission rate (OTR) of 970 mL/m²/day/atmosphere.)
- MA2, 50 µm polyethylene clipseal bag. (Film specification: Low density polyethylene with an OTR of approximately 4,250 mL/m²/day/atmosphere.)

Respiration rate in air was measured in conjunction with the packaging trial at each temperature. Carbon dioxide from respiration was measured from a 1 mL headspace gas sample taken from the respiration chamber upon closing and then again approximately 2 hours later. Samples were processed with an infrared gas analyser (IRGA). Respiration rate was measured as CO₂ production rate in mL/kg/hour and was calculated as follows: $[\Delta\%CO_2 \times 10 \times \text{free volume (L)}] / [\text{Produce fresh weight (kg)} \times \Delta\text{time (hours)}]$.

Oxygen and carbon dioxide levels in the packages were measured with a Novatech portable gas analyser. Pieces of Rehaus silicone tape were stuck to the exterior of each pack to act as septa and to enable consecutive measurements without leaks.

A rating scale of 1 to 5 was used to assess turgor, colour, rots, and the general appearance (1 = excellent quality, 5 = very poor) of the produce following storage and again after 3 days of simulated marketing.

Results

Perilla was successfully stored in MA2 bags at 0°C and 4°C for up to 13 days plus an additional marketing period of 3 days at 8°C. Differences in product quality between 0°C and 4°C were minimal.

Levels of atmosphere modification in all package types are shown in Figures 1 and 2. Through the later part of the storage time in MA2 at 4°C, the oxygen level averaged around 14% and carbon dioxide was close to 6%. In comparison, at 0°C the MA2 atmosphere was about 17% oxygen and 4% carbon dioxide.

Compared with MA1 and control bags, the general appearance of perilla stored in MA2 bags was significantly better. The odour of perilla stored in MA2 packages was also superior after the marketing period. Similarly, in comparison with MA1 and control bags, produce stored in MA2 was significantly more turgid and had developed fewer rots. MA2 bags also played a significant positive role in maintaining the purple leaf colour.

MA packaging was found to provide storage benefits for Chinese garlic chives, spearmint, hot mint, Thai basil, snake beans, perilla, hot chillies, pak choi, baby pak choi, kangkong, and kai choi. The storage and packaging recommendations for these crops are summarised in Table 1. Although there are literature reports that coriander would benefit from controlled atmosphere or modified atmosphere storage, it was not evident in these trials. Similarly, the storage life of amaranth was not enhanced by MA packaging.

In general, the benefits of modified atmosphere packaging were a reduction in the incidence of rots and yellowing. For chilling-susceptible produce such as snake beans, kangkong, and Thai basil, MA also reduced chilling injury. Lower incidence of mould on the peduncles or stems, and a reduction in peduncle shrivelling were major benefits for hot chillies stored in MA bags.

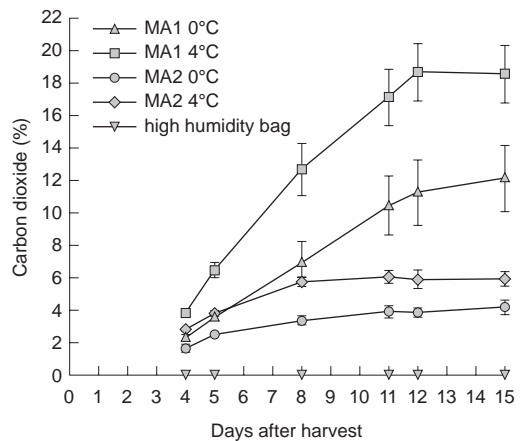


Figure 1. Carbon dioxide levels in three package types for perilla stored at two temperatures.

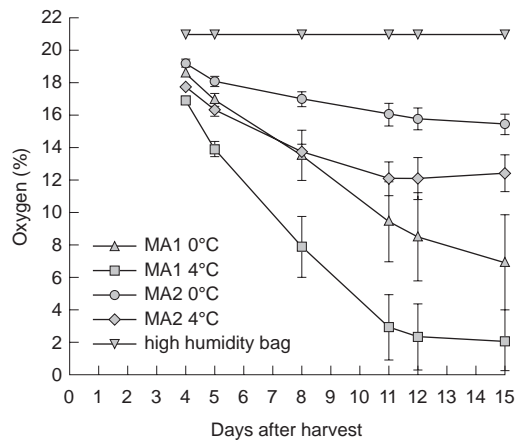


Figure 2. Oxygen levels in three package types for perilla stored at two temperatures.

Temperature is a critical factor in maintaining product quality during storage. Most of the produce types reported here are best when stored at 0°C. However, Thai basil, snake beans, and kangkong are susceptible to chilling injury if exposed to low storage

temperatures, and Thai basil and snake beans should not be exposed to temperatures below 12°C.

Packaging trials for kangkong were conducted at 4°C and 8°C; the literature recommends storage temperatures varying from 0 to 9°C (Hirata et al. 1987). Chilling injury symptoms developed during the pack-

aging trials reported here, suggesting that the optimum storage temperature for kangkong is higher than 8°C.

Initial high quality of produce is essential for good outturn following storage in modified atmosphere packaging. MA packaging will not improve the initial product quality. MA should always be used in con-

Table 1. Storage and packaging recommendations for Chinese garlic chives, spearmint, hot mint, Thai basil, snake beans, coriander, perilla, hot chillies, pak choi, baby pak choi, kangkong, kai choi, and amaranth.

Product	Storage temperature (°C)	Observed MA benefit	Recommended packaging	Additional requirements
Chinese garlic chives (<i>Allium tuberosum</i>) (5 bunches)	0–4	yes	50 µm polyethylene clipseal bag (355 × 400 mm)	
Spearmint (<i>Mentha spicata</i>) (5 bunches)	0	yes	50 µm polyethylene clipseal bag (355 × 400 mm)	Treatment for prevention of leaf abscission
Hot mint (<i>Polygonum odorata</i>) (5 bunches)	0	yes	50 µm polypropylene bag (Rayopp RH50) (270 × 350 mm)	Control of two-spotted mites
Thai basil (<i>Ocimum tenuiflorum</i>) (5 bunches)	12	yes	50 µm polyethylene clipseal bag (355 × 400 mm)	Storage temperature is critical for prevention of chilling injury
Snake beans (<i>Vigna unguiculata</i> subsp. <i>sesquipedalis</i>) (100 g)	12–15	yes	Rob's medium longlife bag (300 × 450 mm)	Storage temperature is critical for prevention of chilling injury
Coriander (<i>Coriandrum sativum</i>) (20 bunches)	0	no	High humidity air	
Perilla (<i>Perilla frutescens</i>) (3 bunches)	0–4	yes	50 µm polyethylene clipseal bag (250 × 330 mm)	
Hot chillies (<i>Capsicum annum</i> var. <i>annuum</i>) (100 g)	0–4	yes	75 µm polypropylene bag (Rayopp RH50) (150 × 120 mm)	Alternative packaging: 50 µm polyethylene clipseal bag (150 × 205 mm, sealed at 120 mm)
Pak choi (<i>Brassica rapa</i> var. <i>chinensis</i>) (5 bunches)	0	yes	Fresha-pak medium or high transmission polyethylene bag (865 × 875 mm)	
Baby pak choi (<i>Brassica rapa</i> var. <i>chinensis</i>) (12 bunches)	0	yes	Fresha-pak medium transmission polyethylene bag (865 × 875 mm)	
Kangkong (<i>Ipomoea aquatica</i>) (12 bunches)	9	yes	Fresha-pak medium transmission polyethylene bag (865 × 875 mm)	Determination of optimum storage temperature
Kai choy (<i>Brassica juncea</i>) (12 bunches)	0	yes	Fresha-pak medium transmission polyethylene bag (865 × 875 mm)	
Amaranth (<i>Amaranthus tricolour</i>) (12 bunches)	0–4	no	High humidity air	

junction with appropriate postharvest handling protocols and proper cool-chain management.

Cold Storage to Extend Shelf Life and Improve Quality of Chinese Waterchestnut

A traditional vegetable in Asia, Chinese waterchestnut (*Eleocharis dulcis*) is emerging as a new commodity in Australia with potential for export. Postharvest storage protocols have been sought by growers to extend the shelf life and thereby extend availability for domestic and, in the future, overseas markets. The effects of packaging and storage temperatures on shelf life and quality of waterchestnuts have been studied in Australia since 1997.

While some quality factors such as corm size and colour are principally determined by the growing environment and cultivation practices, other quality parameters are affected by postharvest storage practices. These parameters include weight loss, sprouting, growth of moulds on the external peel, discolouration and development of rots in internal tissues, and changes in sugar content of corms. Once one parameter falls below a critical level the shelf life of waterchestnuts is essentially ended. For example, if weight loss causes shrivelling of the corms' peels, they are considered unacceptable to consumers even though there are no signs of moulds and internal rots.

Although recommendations for postharvest storage were published as early as 1955 (Hodge and Bisset 1955), only a few systematic studies have been conducted to determine the shelf life of fresh waterchestnuts under various storage conditions. Some studies (e.g. Brecht et al. 1992) tested the effect of storage temperature on weight loss, sprouting, and sugar content of waterchestnuts. As in other tuber crops, higher storage temperatures induced sprouting and shortened shelf life by increasing weight loss through transpiration and respiration.

In tuber crops such as potato, with starch as the primary carbohydrate storage compound, low temperature storage causes unacceptable 'sweetening' of tubers. This process of sugar formation from starch in potatoes has been found to accompany four circumstances: (1) low temperatures (particularly below 10°C); (2) sprouting; (3) senescence; and (4) decay following wounding and fungal infection (Burton et al. 1992). However, 'sweetness' is appreciated in Chinese waterchestnut. Therefore, to minimise weight loss in stored waterchestnuts and to promote sweet-

ness, different packaging materials, storage temperatures, and storage durations were tested and are reported here. Data were collected on the effect of storage temperature and storage period on the 'total soluble solids' (TSS) content which is an indicator of sugar levels in many agricultural commodities.

In assessing quality, corms that had lost more than 10% of their fresh weight were considered visually unacceptable. When stored in the open, waterchestnuts lost this proportion of their fresh weight within one week. However, when corms were packaged in low-density polyethylene (LDPE) film (i.e. 'snap-lock' bags) or microperforated LDPE film (i.e. 'Longlife' vegetable bags), loss of fresh weight was within the acceptable level over a 5-month storage period regardless of the storage temperature tested (1°C and 9°C). The packaging materials did not differ significantly in their efficacy in reducing fresh weight loss in stored waterchestnuts.

Compared with some other horticultural products, it was found that respiration rates in waterchestnut were low to very low (0.6–1.2 mL CO₂/kg/hour). Based on this, weight loss caused by respiration was calculated to comprise only 3% of fresh weight loss of corms stored for one month at 1°C. Therefore, weight loss of openly-stored waterchestnuts is primarily confined to transpiration, which can be successfully reduced by using packaging materials that are minimally permeable to water-vapour transfer.

Although weight loss of waterchestnuts did not differ across the two storage temperatures tested, difference in storage temperature did eventually affect development of moulds and rots. Not surprisingly, superficial fungal growth was accelerated at the higher storage temperature of 9°C but internal rots developed more rapidly at 1°C. This latter result may have been due to fluctuations in the trial's storage temperatures which could have reduced corm temperatures to below 0°C, thereby causing chilling injuries and associated rots. Moulds and rots shortened the storage life of waterchestnuts to 3–4 months at either storage temperature.

With the exception of the value for the 2-week storage period, sugar content (as indicated by TSS) increased over the first 12 weeks of storage (Figure 3). This was accelerated by the lower storage temperature, which suggests that the same (as yet incompletely understood) processes that cause 'low-temperature sweetening' in potato may also be active in Chinese waterchestnut. At present, we have no explanation for the drop in TSS after 12 weeks and then the rise at 20 weeks (Figure 3).

Preliminary results from current research suggest that, aside from low temperature, the other processes that explain sweetening in potato have no or only limited validity in waterchestnuts. At higher storage temperatures, sprouting was accelerated but sweetening did not occur; corm senescence was hastened by higher temperatures but this inhibited sweetening; and decay after wounding and fungal infection did not enhance sugar content.

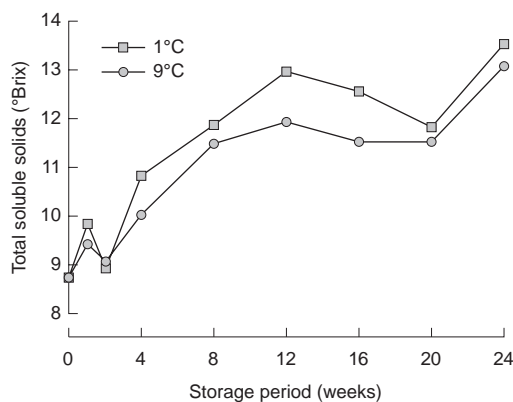


Figure 3. Effect of storage temperature and storage period on sugar content (as indicated by total soluble solids) in Chinese waterchestnut corms.

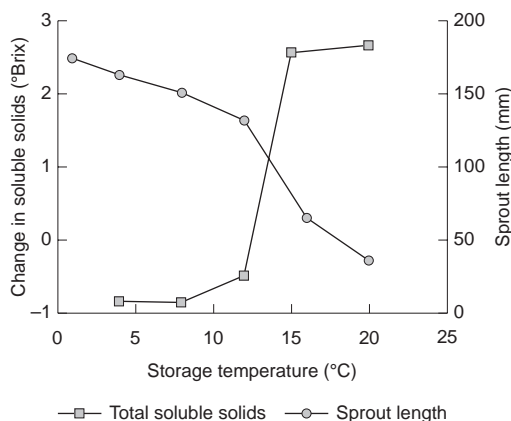


Figure 4. Relationship between storage temperature, change in total soluble solids, and sprout length in Chinese waterchestnut corms.

In our current research on storage of Chinese waterchestnut corms, a wider range of storage temperatures (4, 5, 8, 12, 15 and 20°C) has been examined to

determine ‘critical’ temperatures below which sweetening and above which sprouting occurs.

The data presented in Figure 4 show this temperature to be 13.6°C. An attempt is also being made to calculate a ‘TSS per cold unit’ value (i.e. the inverse of heat units). This would make it possible to estimate the TSS content of waterchestnuts when the sum (or perhaps product) of time and temperature at which waterchestnuts were exposed to temperatures below the ‘critical’ temperature is known. Possibly, exposure duration is independent of whether it occurs during the growing period in the field or in postharvest cold storage. To assist in understanding this process, corms have been harvested and tested for TSS during different growth stages, and the development of their TSS is being studied under subsequent cold storage.

Quality Assessment of Kabocha Pumpkins

The word ‘kabocha’ in Australia refers to varieties of pumpkin preferred by Japanese consumers. Kabocha varieties are either intraspecific crosses between different lines of *Cucurbita maxima* or interspecific crosses between *C. maxima* × *C. moschata*. The name ‘Japanese pumpkin’ is also used.

Kabocha pumpkins are typically quite small (1–2.5 kg) and have a distinctly sweet, nutty flavour. Agronomic requirements are similar but not identical to pumpkins traditionally grown in Australia. However, Japanese consumer expectations of taste and quality are substantially different from Australian expectations.

A number of separate efforts have been made in Australia to research and develop this crop for export to Japan and to expand sales on the domestic market. Japanese consumers prefer firm pumpkins with dark green skin and dark orange flesh. A dulled (not shiny), evenly distributed green is most marketable (Jeff Hastings 1998, pers. comm.). Uniformity of colour is most affected by the earth mark (where the fruit sits on the ground) and sunburn. Warts and other blemishes can also be a problem. Warts are superficial raised corky lesions thought to be associated with maturity and excessive soil moisture. Susceptibility to both warts and sunburn varies among varieties, with sunburn being at least partially dependent on leaf coverage and time of harvest.

Japanese and Australian kabocha appear to differ more in nuttiness than sweetness and this dictates a huge difference in price (Vong Nguyen 2000, pers.

comm.). Brix is increased by greater exposure to sunlight and diurnal temperature variation. Hence, quality tends to be better when grown inland. Desired specifications vary with the market, particularly between fresh and semiprocessed. Carotenoids are considered to have health benefits, so a market could be developed around high nutrition fruit based on carotenoid levels.

Mainland Australia is currently restricted from exporting fresh kabocha to Japan owing to the presence of fruit fly. Therefore, until disinfestation procedures have been worked out, only the island state of Tasmania can export, as it has fruit-fly-free status. Tasmanian first grade pumpkins have been exported to Asia and Japan for the last 6–10 years with current volumes at approximately 1000 t/year. About 30% of production is rejected for skin blemishes and sunburn. Australia must produce kabocha for a high quality niche market to be competitive against kabocha pumpkins exported by New Zealand.

About 28,000 t of kabocha was processed in Japan in 1991, yet there were few processed imports. Most was processed by cutting and freezing for both food service and retail markets (Pan 1995). Frozen produce is used for soup and to produce sweet cream for cakes and is also sold in supermarkets for home use (JETRO 1996). Australia could well establish a market in this product as long as the price is internationally competitive.

Trials around Australia have sought to analyse the quality of kabocha fruit from different varieties, to establish which best meet the requirements for sales in Japan. Results from Tatura (northern Victoria) and Katherine (Northern Territory) for one season are presented in detail here. There is interest at both sites in kabocha production for Japan, and both sites use greatly differing agronomic practices to suit the local environment. Some general results on carotenoid content of pumpkins conclude this section.

Materials and methods

After harvest, pumpkins were stored for 20 days at 15°C, then assessed for quality. At higher temperatures, the pumpkins dry out (Larkcom 1991) and at lower temperatures they suffer chilling injury even if the temperature is too low for only a few days (Rubatzky and Yamaguchi 1997).

Assessments

Skin colour

Ground (or background) colour lightness/darkness of the skin was evaluated. Striping (striping could be darker or lighter than the ground colour) and blotching of the skin (over the ground colour) were not considered. Five subjective categories of skin darkness were established and linked by eye to colours from the Royal Horticultural Society (RHS) Colour Chart (Table 2). Uniformity of ground colour darkness was assessed as ‘even’ or ‘uneven’.

Table 2. Evaluation categories for skin colour lightness/darkness of kabocha pumpkins.

Category	Subjective description	RHS ^a colour chart approximation
1	Pale	137C
2	Light	137B
3	Medium	136B
4	Dark	136A
5	Very dark	Darker than 136A, ranging through to black

^a Royal Horticultural Society

Flesh colour

Flesh colour characteristics were deemed more important than skin colour and consequently these were investigated more fully. Flesh colour was assessed using the RHS colour chart and an electronic colour meter (Chroma Meter, Minolta model CR-200) calibrated using the white tile:

$$(L^* = 97.75, a^* = -0.43, b^* = +2.09).$$

The Chroma meter CR-200 generated figures for L^* , a^* , and b^* . Chroma (saturation) = $(a^{*2} + b^{*2})^{1/2}$. Hue angle (H°) = $\tan^{-1}(b^*/a^*)$.

Warts

The presence of warts and/or blemishes on the skin was noted as simply ‘present’ or ‘absent’. The point of ground contact was not deemed a blemish.

Sugars

Sample preparation. Peeled pumpkin (50 g) was blended with 50 mL water for 1.5 minutes. The mixture was then transferred into a 250 mL beaker. Five mL of Carrez-I solution (85 mM $K_4Fe(CN)_6 \cdot 7H_2O$) was added and the solution mixed. This was

followed by 5 mL of Carrez-II solution (250 mM ZnSO₄·7H₂O). NaOH (0.1 M) was then added to adjust the pH to 7.0–7.5. This mixture was transferred into a 250 mL volumetric flask and filled to volume with water. A sample of the solution was then prepared for analysis using a 0.45 µm syringe filter.

Analysis of sample. A Boehringer Mannheim kit for the determination of sucrose/D-glucose/D-fructose in foodstuffs using an ultraviolet method was employed. The procedure followed was that outlined in the kit's instructions.

Carotenoids

Flesh samples taken at Knoxfield were frozen and held at –70°C for up to a month before delivery to the State Chemistry Laboratories (SCL) for carotenoid analysis. SCL had advised that carotene levels in frozen samples would remain stable for at least 6 weeks.

SCL procedure. Total carotenoids were determined in kabocha samples after saponification with 100% w/v potassium hydroxide under reflux for 30 minutes according to AOAC (1990). Carotenoids were then extracted with hexane. Hexane extracts were analysed for total carotenoids using UV spectrophotometry at 450 nm, according to the method of Siong and Lam (1992).

Statistical analysis

All least significant differences for the kabocha results were generated with one-way analysis of variance based on individual separate cases i.e. one case = one pumpkin.

Results and discussion

Pumpkins produced at Tatura

Thirty-six pumpkins were received from Tatura in mid-April 2000. There were 12 fruit each of the culti-

vars 'Pacifica', 'Delica', and 'Kurijiman'. Means for some of the quality assessments appear in Table 3. All of the Tatura fruit had uneven skin colour and warts/blemishes.

Japanese consumers prefer pumpkins with dark green skin and dark orange flesh. The skin of 'Delica' was significantly darker than that of 'Pacifica'. In comparison, skin darkness of 'Kurijiman' was intermediate but not significantly different from the other two varieties.

The more highly desirable flesh colours (e.g. Royal Horticulture Society chart 23A) have lower L* readings (represents darker) and lower hue values (represents a more yellow colour). Vivid colours have high chroma values and dull colours have low chroma values. Flesh with a 23A chart match is bright orange, the electronic colour match description being: L 77.88, hue 78.23, chroma 82.83. Some pumpkin flesh samples scored as RHS chart 22B and looked pale and dull. Their electronic description was L 83.61, hue 83.33, chroma 54.65.

Judged against the RHS colour chart, the flesh of all samples fell within the yellow–orange group (Table 3). More importantly, flesh generally matched the 'brighter/stronger' colours (as judged by the eye), within the yellow–orange group. Lower L* readings for 'Pacifica' suggest an overall darker flesh colour for this variety. The hue rating for 'Delica' was significantly higher (i.e. yellower) than that of 'Kurijiman' and 'Pacifica'. 'Delica' had a significantly higher chroma result than the other two varieties.

Average total sugars in 'Pacifica' were the lowest of the three varieties and significantly lower than the total sugar levels found in 'Delica' (Table 3). Sugar levels in 'Kurijiman' were intermediate and not significantly different from the two other varieties. The higher sugar content in 'Delica' is an observation consistent with findings in the previous year's trials.

Table 3. Comparison of quality traits for three kabocha pumpkin varieties grown at Tatura in Victoria, Australia.

Variety	Skin darkness	Flesh colour L (value)	Flesh colour hue	Flesh colour chroma	Total sugars (g/100 g)
'Delica'	3.58	67.28	79.65	74.51	1.29
'Kurijiman'	3.42	67.09	77.96	72.52	1.22
'Pacifica'	3.25	64.37	77.48	70.95	1.14
LSD (P = 0.05)	0.24	2.17	1.34	1.79	0.13

Pumpkins produced at Katherine

Fifty-nine pumpkins of varieties ‘Kurijiman’ (n=10), ‘Tetsukabuto’ (n=10), ‘Pacifica’ (n=10), ‘Delica’ (n=10), ‘Sweet Mama’ (n=10) and ‘T110’ (n=9) were received from the Northern Territory in mid-October 2000. Uniformity of skin colour varied considerably between varieties. In Japan, an evenly distributed green is most marketable. Of the six varieties supplied from Katherine, ‘Tetsukabuto’ and ‘Sweet Mama’ were rated with the most evenly coloured skins (Table 4). All samples of ‘T110’ had uneven skin colour.

Skin darkness varied between the varieties planted at Katherine. ‘Tetsukabuto’ and ‘T110’ skins were significantly darker than those of all other varieties. Differences between ‘Kurijiman’, ‘Pacifica’, ‘Delica’, and ‘Sweet Mama’ were not significant (Table 4).

In general, warts and blemishes were less prevalent on samples from Katherine than those from Tatura. Of the Katherine fruit, the best variety was ‘Tetsukabuto’, of which 50% were wart/blemish free. However, other than ‘Sweet Mama’, the ‘Tetsukabuto’ result was not significantly higher than that for the other cultivars. All ‘Sweet Mama’ samples had warts/blemishes.

As for Tatura, visual differences between the Katherine-grown varieties in flesh colour were not obvious. However, 40% of the ‘Pacifica’ samples matched 21B on the RHS Colour Chart and this colour is visually

less ‘strong/bright’ than most other colour matches made for the Katherine samples.

All the varieties grown at Katherine had average readings for L that were greater than those for Tatura pumpkins. This suggests that the southern growing site produced darker and more desirable flesh. Of the Katherine samples, ‘Tetsukabuto’ had the darkest average flesh colour (Table 4). ‘Kurijiman’, ‘Pacifica’, ‘Delica’, and ‘Sweet Mama’ had significantly lighter flesh than ‘Tetsukabuto’. ‘Kurijiman’ grown at Katherine had significantly lighter flesh than ‘Tetsukabuto’, ‘T110’ and ‘Sweet Mama’ from the same site.

Average hue values were lowest (i.e. more favourable) for ‘T110’ and highest for ‘Kurijiman’. However, many of the differences between these two extremes were not significant.

‘T110’ flesh averaged the highest chroma values of all varieties, with a significantly higher mean than ‘Kurijiman’, ‘Pacifica’, and ‘Delica’ (Table 4). ‘Delica’ had the lowest chroma value, significantly lower (and therefore duller) than the flesh of ‘Tetsukabuto’ and ‘T110’.

Of the Northern Territory samples, ‘Delica’ had the highest total sugar level (1.81g sugar/100 g flesh). However, this level was only significantly higher than the levels observed in ‘Tetsukabuto’ and ‘T110’.

Table 4. Comparison of quality traits for six kabocha pumpkin varieties grown at Katherine in the Northern Territory, Australia.

Variety	% of sample that contained fruit with even skin colour ^a	Skin darkness	% of sample that contained fruit which were wart/blemish free*	Flesh colour L (value)	Flesh colour hue	Flesh colour chroma	Total sugars (g/100 g)
‘Kurijiman’	10bcd	1.7	40a	74.17	79.95	70.84	1.63
‘Tetsukabuto’	60a	4.0	50a	67.57	77.91	75.11	1.51
‘Pacifica’	40abc	2.1	30ab	72.67	79.08	71.09	1.61
‘Delica’	50ab	2.3	30ab	71.35	78.32	70.70	1.81
‘T-110’	0d	3.8	33a	69.10	76.91	77.24	1.50
‘Sweet Mama’	60a	1.7	0b	71.02	78.80	74.23	1.64
LSD (P=0.05)	–	0.67	–	2.97	1.52	3.64	0.24

^a Percentages (within the column) followed by a different letter are significantly different (Chi-square test, P = 0.05)

Twenty samples (unreplicated) for carotenoid analysis were received from Gatton (Queensland), Gosford (New South Wales), Swan Hill (Victoria), and Katherine (Northern Territory). There was considerable variability between the carotenoid content of the individual samples. The lowest reading was 3.0 mg/100 g for a 'Pacifica' sample grown at Swan Hill, while a 'Sweet Mama' sample from Gosford gave the highest of 13.3 mg/100 g (Figure 5). The mean for the 20 samples was 8 mg/100 g.

Based on the limited number of results available, it would appear that traditional varieties like 'Delica' and 'Pacifica' generally had lower carotenoid levels than some of the newer varieties such as 'Tetsukabuto'. An interaction with growing site is likely but small sample numbers from the different trial sites prohibit rigorous analysis. As well as possessing many of the more desirable quality traits, it is interesting to note that 'Tetsukabuto' was also a high yielding variety and therefore one that is likely to be increasingly planted.

This preliminary work shows that there may be different carotenoid levels between cultivars and production sites. More work is required to determine which cultural practices, cultivars, and growing regions result in maximal carotenoid levels. This information could then be used as a powerful marketing tool to promote the health benefits of Australian kabocha.

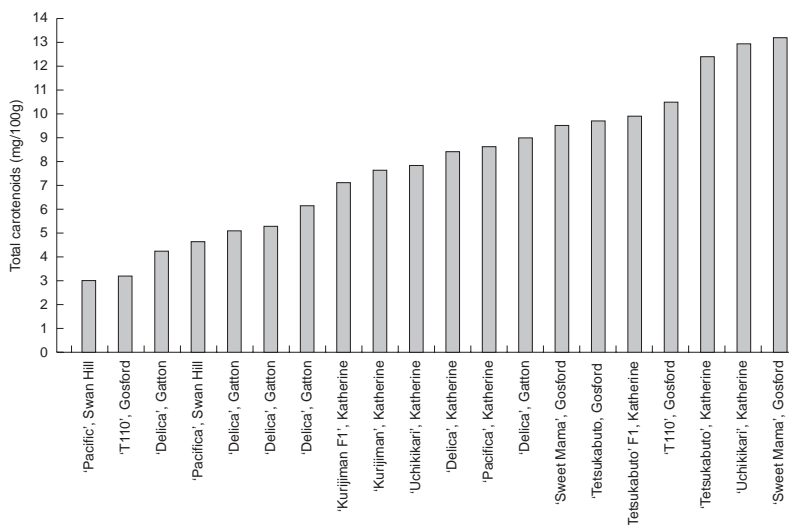


Figure 5. Total carotenoid levels in 20 kabocha pumpkin samples.

Acknowledgments

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References

- AOAC (Association of Official Analytical Chemists) 1990. Official methods of analysis, 15th ed. Arlington, VA, USA, Section 974.29.
- Brecht, J., Bergsma, K., Sanchez, C., and Snyder, G. 1992. Harvest maturity and storage temperature effects on quality of Chinese waterchestnuts (*Eleocharis dulcis*). *Acta Horticulturae*, 318, 313–319.
- Burton, W., Van Es, A., and Hartmans, K. 1992. The physics and physiology of storage. In: Harris, P.M. ed., *The potato crop*, 2nd ed. London, Chapman & Hall, 608–727.
- Hirata, K., Chachin, K., and Iwata, T. 1987. Changes of K⁺ leakage, free amino acid contents and phenylpropanoid metabolism in water convolvulus (*Ipomoea aquatica* Forsk.) with references to the occurrence of chilling injury. *Journal of the Japanese Society for Horticultural Science*, 55(4), 516–523.
- Hodge, W. and Bisset, D. 1955. *The Chinese waterchestnut*. Washington, DC, US Department of Agriculture, Circular 956.

- JETRO (Japan External Trade Organisation) 1996. Process vegetables: your market in Japan — 1996. (URL: <http://www2.jetro.org/Database/ymj/ymj97705.htm>)
- Larkcom, J. 1991. Oriental vegetables: the complete guide for garden and kitchen. London, John Murray, 232p.
- Pan, C. 1995. Market opportunities for fresh and processed Asian vegetables. Canberra, Rural Industries Research and Development Corporation, RIRDC Research Paper No. 95/14, 117p.
- Rubatzky, V. and Yamaguchi, M. 1997. World vegetables; principles, production, and nutritive values. New York, Chapman and Hall, 843p.
- Siong T. and Lam L. 1992. Analysis of carotenoids in vegetables by HPLC. ASEAN Food Journal, 7, 91–99.

Australian Postharvest Technologies for Fresh Fruits and Vegetables

Richard McLauchlan and John Bagshaw*

Abstract

General postharvest handling systems and technologies used in Australia for broccoli and other fruits and vegetables from harvest to wholesale market are presented to contrast with those in China. With production areas usually a considerable distance (e.g. 100 to 3500 km) from the major markets in the capital cities, appropriate systems and technologies are needed to minimise losses and maintain product integrity and quality while ensuring food safety. Aspects covered include field harvest (harvest aids, packing), packing houses (handling, grading, sorting, packing, cooling, pallet/unitisation), storage and transport (refrigeration, mixed loads), and wholesale markets.

WHILE Australia and China are of comparable areas, their horticultural production, storage, and distribution systems are markedly different. In China, the average horticultural farm holding is relatively small — around 0.2 to 0.8 ha (Beijing Vegetable Research Center and Hangzhou University of Commerce, pers. comm.). Produce is sold directly from the farm to collectors (wholesalers) who organise transport to the major markets, for export and retail distribution. Australian farms are considerably larger (at least 100-fold) with many growers operating their own packing houses and coolrooms. Distances from major production areas to the principal markets in the capital cities range from less than 100 km to over 3000 km. Australian systems are designed to minimise expensive labour costs while maintaining product quality throughout the transport, distribution, and marketing systems, as the grower may receive no return for his produce until it passes through the wholesale market.

* Queensland Horticulture Institute, Department of Primary Industries, 80 Meiers Road, Indooroopilly, Queensland 4068, Australia.

Harvest Aids

The most common harvest aid is the bulk bin (Figure 1). Many fruits and vegetable are harvested directly into bulk bins (capacity 0.5 t, external dimensions 116 × 116 cm × 70–80 cm high) or via smaller harvest packs which are emptied into bins in the field. Bins are usually transported promptly to the packing house when filled. More sophisticated systems for lettuce, celery, and Chinese cabbage include conveyor belts, shading, and packing into cartons in the field (Figure 2). In these cases, full pallets of packed produce go directly to the packing house coolrooms.

Occasionally, harvest aids are developed to overcome specific harvest problems. For example, the Australian ‘Kensington Pride’ mango is sensitive to the sap exuded when the stem is cut. Fruit may stain or develop a more serious ‘burn’ injury which significantly reduces fruit quality. The mango harvest aid allows mangoes to fall onto a tarpaulin sprayed with a detergent solution (Figure 3). The tarpaulin causes no impact damage from the drop while the detergent disperses any mango sap, preventing fruit injury.

Highly mechanised harvest aids used in the tomato industry allow cost-effective large volume harvesting while reducing the physical strain (to humans) of

picking. Blocks of tomatoes may be picked 15–30 times every 2–3 days over 4–12 weeks. Labour costs are minimised using a tomato harvester (Figure 4).

Packing House

The general operations in a packing house might include: a preliminary inspection to remove excess field trash and damaged produce when the bulk bins are emptied onto the packing line; washing, fungicide or insecticide application, waxing and drying (as applicable); quality grading, size grading, labelling and packing; palletising of packed cartons; and cooling to appropriate holding or carriage temperatures.

The use of postharvest chemicals in the packing house (fungicides, insecticides) is regulated by appropriate health or food authorities and individual treat-

ments will depend on the horticultural produce. While the processing equipment used will be specific for the treatment, the systems used are relatively standard. The packing house must also comply with regulations governing water hygiene and disposal of used chemicals.

The shelf life of broccoli is shortened considerably at ambient compared with storage (1–2°C) temperatures. Consequently, broccoli is cooled (in the bulk bin) as soon as possible after harvest and is refrigerated before packing. The packing house may also be refrigerated (10°C) to minimise temperature rises during sorting, grading, and packing. Broccoli heads are inspected for quality and defects before packaging and return to the coolroom. Chinese cabbage, lettuce, and celery packed in the field go directly to a forced-air coolroom in the packing house.



Figure 1. Harvesting broccoli into bulk bins.



Figure 3. Mango harvest aid reduces sap injury.



Figure 2. Harvesting, trimming, and packing Chinese cabbage in the field.



Figure 4. Tomato harvester for high-volume, labour-intensive picking.

Many fruits and some vegetables are labelled with a small sticker indicating the brand name and/or packing house number. This previously manual operation is now done routinely by modern processing equipment. Similarly, while older style belt and roller size graders are still used (Figure 5), modern equipment uses computer-controlled size graders (either by weight or optically) to channel produce to the appropriate packing lines (Figure 6). Many of these systems also colour-grade produce as it passes through the line. The final packing into cartons is mostly a manual operation but it may be done mechanically (Figures 7 and 8). Generally, only packing houses with a very high throughput can afford this system.

Cooling

Temperature is the most important factor in maintaining product quality and maximising shelf life

through the marketing chain. The higher a product's respiratory heat, the more critical it is to rapidly remove field heat and hold the product at its optimal storage temperature.

Broccoli and sweet corn have a high respiratory heat. Apart from refrigeration for initial cooling, ice may also be added to ensure temperature rises are minimised. When produce is 'top-iced', it is packed in a suitable waterproof package, usually polystyrene cartons fitted with a lid. The product must also be tolerant of prolonged exposure to wet conditions at 0°C.

Another simple cooling method is hydro-cooling. Bulk bins may be hydro-cooled before packing, either by immersion in cold water or by showering cold water over them. After packing, pallets of produce in open-top waterproof cartons may be hydro-cooled by showering with cold water. Water is recirculated through a refrigeration system, and again the produce must be tolerant of wet conditions.



Figure 5. A common belt and roller size-grader for mandarins.



Figure 7. Manually labelling and packing oranges.



Figure 6. Computer-controlled orange size-grader.

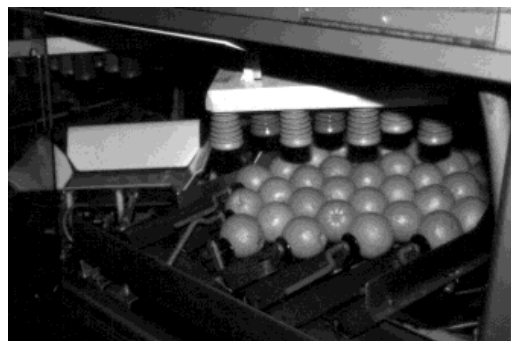


Figure 8. Mechanised orange packing.

Refrigerated room cooling is the most common form of cooling for fruits and vegetables. However, cooling of packed, palletised produce can be quite slow in a static coolroom system, as very little cold air penetrates the stow and makes contact with the produce. Forced-air systems considerably improve the rate of cooling and make more efficient use of refrigeration (Figure 9).

Vacuum cooling is another, but less common, cooling method suitable for leafy vegetables such as lettuce. Applying a vacuum to the produce causes evaporation of water and associated cooling. Every 6°C of cooling is accompanied by a 1% moisture loss but this can be reduced by spraying produce with water before or during the cooling process. Vacuum and hydro-cooled produce should be transferred to an appropriate coolroom as soon as possible after cooling to maintain the desired temperature.

Packaging

The most common packages for fruits and vegetables are made of fibreboard, sometimes waxed to increase strength, especially where free moisture may be encountered. Polystyrene packages are also common although disposal of used packages can be a problem. Various inserts (fibreboard dividers, paper wraps, plastic or fibreboard trays, plastic containers, plastic films) may also be used, depending on the produce. Most fibreboard cartons are used only once, occasionally twice, while polystyrene cartons may be used a little more often. At \$1 to \$2 each, depending on

design and construction, carton cost is a significant expense, especially with lower-value produce.

Plastic crates have been introduced periodically but have not proven popular to date. The major carton manufacturers are currently trialing returnable plastic packages for fruits and vegetables. These would be rented rather than bought, as is currently the case for fibreboard and polystyrene cartons. Multiple use of the same package could reduce packaging costs to around 10–20% of those at present.

Attempts have also been made to introduce a small range of standard-size packages. Again, this has not proven popular and many carton designs are currently used. The common features of most packages are that they fit reasonably efficiently on the standard Australian pallet, ventilation is designed to allow forced-air cooling, and the package is strong enough to protect its contents throughout the handling systems, though damage does sometimes occur (Figure 10).

The Australian pallet is 1165 × 1165 mm. Pallets are hired from local depots, used for transport to markets, and returned to the market depot. Most cartons are designed so that an integral number of carton widths and lengths equals 1165 mm (allowing for some bulge in the carton). For example, a carton 580 mm long by 385 mm wide would efficiently fit three across (1155 mm) and two along (1160 mm) a standard pallet. Other designs accommodate a pin wheel pattern, e.g. a carton 480 × 335 mm would fit two across and one along ($2 \times 335 + 480 = 1150$ mm) with the stow rotated around the pallet and a central chimney in the middle (Figure 11). This stow is less efficient but is very widely used.

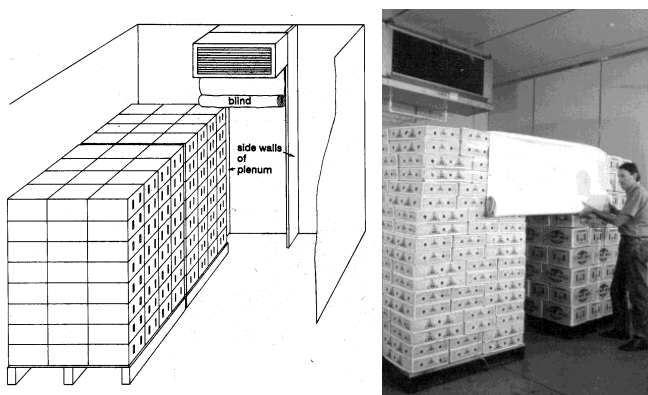


Figure 9. Forced-air cooling principles and operation. Cold air from the refrigeration unit is drawn through the aligned carton ventilation slots producing rapid cooling.



Figure 10. Possible causes of carton collapse: under strength, wet, too high, poorly secured, rough handling.



Figure 11. An 8 per layer pin wheel stow with metal corner posts and strapping to stabilise the load. Alignment of ventilation slots allows forced-air cooling.

A pallet of packed cartons will usually be stabilised by corner posts (heavy fibreboard or metal) and strapping (plastic strap or netting). Bulk bins (timber or very heavy grade fibreboard) are also used as are bags (e.g. for onions and potatoes). Again, these are designed to palletise so that fork lifts and standard storage systems can be used throughout the handling chain.

Transport

The majority of fruit and vegetables is transported by road but rail is also used. Over short distances, non-refrigerated systems are used; over longer distances, refrigerated systems predominate. Loads are palletised and major packing houses and transport company premises are designed to allow fork lifts to drive directly into large, refrigerated trucks. Refrigerated packing houses or distribution centres allow road vehicles to back up to an air lock for loading and unloading. This allows fork lifts to move from packing house to truck under controlled temperatures, maintaining the cool chain.

Refrigeration systems used in road and rail transport do not have the capacity to cool the several tonnes of produce in the load which should therefore be cooled (preferably by forced air) to the appropriate carriage/storage temperature before loading. To minimise transport damage, loads are packed as tightly as possible into trucks. Unfortunately, this also tends to reduce penetration of refrigerated air through the stow and temperatures in the centres of pallets may rise, especially in produce that generates high respiratory heat.

To maximise air circulation, the refrigeration unit should have a plenum to ensure that cold air delivered by the unit can return only via the floor and plenum (Figure 12). The vehicle should also have a suitable air delivery ducting system to deliver cold air along the entire length of the load. Ducted flooring also assists in providing air a clear passage back to the refrigeration unit. Even with good systems, the majority of the air passes over the top layers and side cartons (against the wall), with little air penetrating the centre of the pallet.

Market

The Brisbane wholesale market has a central covered unloading area where produce can be unloaded from trucks. On three sides of this area are the stands of wholesale market agents where produce is sold. Most agents have small coolrooms within their selling area.

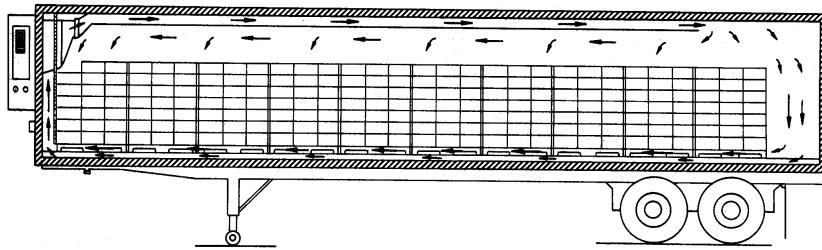


Figure 12. Airflow around palletised load in a refrigerated truck.

They also have larger warehouse storage and cool-room facilities within the market complex. Some also operate ripening rooms, usually forced-air systems with ethylene control.

Some supermarket distribution centres within the market are large refrigerated (15°C) warehouses containing lower temperature coolrooms. Produce received at the centre is held, collated, and distributed as required to the supermarket stores.

When produce is sold (either by agents or distribution centres), pallets are disassembled and restacked with mixed loads. The stability of these loads depends on the degree of similarity between the different cartons/packages purchased. The cool chain is often broken as these loads are transported to local (say up to 100 km) retailers.

A significant difference between the Australian and Chinese systems is that in China, produce is sold many steps back in the market chain, i.e. on farm to the collector (wholesaler). In Australia, the produce is sold

(with respect to the grower) as it passes through the wholesale market.

Recommended Reading

- Hardenburg, R.E., Watada, A.E. and Wang, C.Y. 1990. The commercial storage of fruits, vegetables, and florist and nursery stocks. United States Department of Agriculture, Agriculture Handbook, No. 66.
- Kader, A.A. ed. 1992. Postharvest technology of horticultural crops. Davis, California. University of California Publication 3311. ISBN 0-931876-99-0.
- Watkins, J.B. and Ledger, S. 1990. Forced-air cooling, 2nd ed. Brisbane, Queensland Department of Primary Industries Information Series Q188027.
- Wills, R.B.H., Lee, T.H., Graham, D., McGlasson, W.B., and Hall, E.G. 1982. Postharvest. An introduction to the physiology and handling of fruits and vegetables. Sydney, University of New South Wales Press. ISBN 0-86840-009-2.

Developing a Quality Assurance System for Fresh Produce in Thailand

Sing Ching Tongdee*

Abstract

Implementation of a quality management system leads to an increase in consumer satisfaction and market opportunities. For the fresh produce industry, the decision on the types of quality systems to be used is not always apparent. Understanding the management principles, the implications of international management standards and requirements, and their adoption and adaptation for the fresh produce industry in developing conditions poses an exciting challenge.

Examples of quality management system options for horticultural crops include 'good agricultural (or manufacturing) practice' (GAP or GMP), 'hazard analysis and critical control point' (HACCP), ISO 9000, and ISO 14001. These quality management systems emphasise 'process push'. There is a tendency to stick to procedures, whereas core activities vital to the fresh produce industry, such as leadership and strategic planning, that are ever changing, and supplier/customer management that is 'relationship push', are often neglected. The business of 'risk management' is also unique to the fresh produce industry. The quality of fresh produce cannot be achieved by a single system in a single step in a production or packinghouse operation. Each sector should have its own quality management plan determined by what each one wants out of the quality system.

Against this background, the 'Quality Fruit System 2002' (QFS 2002) was developed. QFS 2002 focuses on helping the horticultural export industry to achieve a valid framework for a quality management system for horticultural crops that meets the international norms while at the same time being feasible under developing conditions. The underlying concept of the system essentially is based on the analytical tool of the 'plan-do-check-act' (PDCA) cycle while working in a total quality management environment. QFS 2002 is presented in a tabulated form. The system describes four elements of requirements and suggests operational details. The requirements allow auditing of the system. The main items of quality documentation are the quality plans. As growers and packinghouse operators are increasingly familiar with the management principles and at ease with the PDCA cycle, they can use the system for other crops or for broader business improvement.

A training manual containing eight training modules has been prepared in anticipation of increasing quality assurance activities in the export of agricultural products. The practical training material is presented in graphic form as standardised instruction materials to be used as introductory training in quality assurance.

* Postharvest Technology Department, Thailand Institute of Scientific and Technological Research, 196 Phaholyothin Road, Chatuchak, Bangkok, 10900. Email: <somsakc@mozart.inet.co.th>.

FRUIT and vegetable production is a tradition in Thailand, and market scenes of the selling of fresh produce are an integral part of the social fabric. As a result of a surplus in production and increasing consumer demand from overseas, a fresh-produce exporting industry emerged in Thailand about a decade ago, initially as an extension of the domestic market. Fresh produce is now moving freely between countries in larger quantities and more rapidly than never before. However, as the infant export industry is still struggling to establish itself, the effect of dynamic market evolution, the challenge of continual social and consumer value changes, and regulatory shifts as a result of globalisation have resulted in a fundamental change in the make-up of the horticultural crop export trade. Market channels for fresh produce today are a great deal different from those just five years ago. In the context of such rapid change, new thinking and new ways of business operation in response to the changing value processes and increasing competitive pressures are required to ensure growth and sustainability of market share. The key to the further expansion of trade is to capture the hearts and minds of consumers, and through quality and quality management. From the initiation of quality concept, through the development of a quality plan, to the implementation of a quality system requires the concerted efforts of participants, from growers to consumers, the support of government institutions, and government–industry cooperation. A quality management system is not academic theories or the pronouncements of government bureaucracies, but rather must be a practical activity focused on the everyday business operations of traders and the industry.

This paper addresses four main topics:

1. the changing concepts of quality and quality management;
2. factors contributing to variability in quality and the unique features of fresh produce marketing;
3. quality management evolution and quality system options for horticultural crops; and
4. simplifying the documentation required for a quality management system for horticultural crops.

The Changing Concepts of Quality and Quality Management

Consumer attitudes towards food have undergone changes and adjustments with changing times. In the late 1970s, price was a major determinant in food purchasing by the consumer. In early 1980s, visual quality and the perception that products were well kept and

attractively presented were prime determinants for consumers. By late 1980s, the consumer trend was toward convenience foods, including fast food, minimally processed food, frozen goods, and ready-to-eat meals. Unlike in earlier years, from 1990 to the present, there has been increasing concern about food safety issues such as pesticide residues and microbial contaminants of food, sanitation of the work environment, personal hygiene of workers, plant health and animal welfare etc. In addition, the linkage of food to health benefits has resulted in the growth of health foods, nutritional foods, and functional foods in the marketplace. There has also been a growing consumer concern about the negative impact of agricultural practices on the environment. This, together with growing scepticism about advanced technology, has led to the development of a niche market for organic food.

The concept of ‘quality’ is changing too. People define quality in many ways. Most consumers think of quality in terms of superior products, but others see it in terms of a range of characteristics, including low price, lack of manufacturing defects, fitness for use, conformance to requirements, and speed and friendly service. However, that quality meets consumer requirements is not enough. For a business firm, quality means productivity, operational efficiency, and profit, and the viability that will enable it to continue to satisfy consumers. Quality is not the highest grade, but rather the appropriate grade. ‘Quality’ has changed from ‘production push’ to ‘market pull’. Quality improvement has moved from being based on product inspection, to a new process-based concept embracing the totality of product, process, service, and organisational management. Quality is about continual improvement and is no longer based on inspection or technology but rather is achieved through product innovation and process improvement, and implementing a quality management system.

The following 10 ‘Ps’ present a multidimensional, customer-focused quality concept that embraces evolving inputs–process–outputs and consequences, which are built on and interact with each other. The 10 Ps collectively achieve product conformance quality by ‘designing the value’, the performance quality of the product and the process by ‘providing the value’, and market-driven quality by ‘communicating the value’, the last-mentioned also including legislative or industry requirements. Planning for quality activities and priority for action depend on which feature or element of the process is being studied.

- *Product*: stands for conformance qualities including variety, diversity, design, product characteristics,

quality, specific features, specification/standards, branding, product packaging, labelling, and presentation.

- *Price*: embraces the price of the product, competitors' prices, the perceived value of the product by the consumer, the amount of money that customers have to pay, and the use of pricing strategies to provide best value for the producers and the consumers.
- *People*: covers worker skills, competence, and motivation. The leaders' ability to plan and lead interactively, and to organise, mobilise, and manage workers. For a technology company this may include the technical vitality of the people/team.
- *Place*: stands for the various activities required to make the product accessible to the customer. It also includes an adequate working environment and facilities, and an attractive business environment
- *Performance*: embraces performance quality—the ability to ensure that the outputs or consequences of product or quality activities deliver their functions/values. Often such information can also be obtained through customer complaints after sale.
- *Purpose*: stands for market-driven quality. It covers the customer's association of product characteristics with things other than conformance qualities, such as image, style, fitness for use etc. that affect the buying decisions of consumers. It requires an understanding of customer motivation and purchasing behaviour, and information on the customer profile and the role of purchasing. Market-driven quality requirements also may relate to conformance to mandatory regulatory and legislative requirements and voluntary industry standards.
- *Productivity*: productivity of the business operation takes into consideration appropriate scales of operation, economies of scale, and operational efficiency.
- *Profit*: covers production/operation with sufficient profit to ensure business viability. It also includes an understanding of the challenges of competitors,
- *Perception*: relates to customers' views on product values and performance, based on information transmitted by 'word of mouth'.
- *Positioning*: embraces where the operator intends to position their product in the marketplace and their ability to communicate its values to potential customers.

The business operation will need to demonstrate its ability to 'design', to 'provide', and to 'communicate' its values based on an understanding of constantly

changing consumer and marketing requirements. Not all of the 10 Ps could be simultaneously implemented or adjusted in the short term. Typically, a firm will make periodic changes based on its policies, core values, and higher priority business objectives, deciding whether to focus on one or on several inter-related features.

Factors Contributing to Variability in Quality and the Unique Features of Fresh Produce Marketing

Factors contributing to variability in quality arise during production, harvesting, postharvest handling, packinghouse operation, distribution and delivery, and marketing. Fresh produce growing is highly seasonal, risky, and the variables affecting quantity and quality often are difficult to predict and control. Quality varies with the levels of skill and management of the grower. Export operations depend on sourcing from different farms of varying quality levels. For some produce, such as durian, the maturity stage at harvest is one of the most critical control points to ensure good eating quality. Many types of produce remain metabolically active after harvest, and most are highly perishable. Quality requirements vary depending on markets. Market information requires close monitoring and continuous, rapid feedback.

From farm to table, the fresh produce handling chain is fragmented and involves a large number of small players each with their own ideas. Stakeholders consist of farmers, farm contractors, harvesters, collection centre or packinghouse operators, packers, distributors, exporters, importers, and consumers. The composition of the chain and how effectively it is managed have very important bearing on quality. Quality of fresh produce cannot be achieved by a single system in a single step of operation, but is the sum of the contributions of component sectors/partners along the handling chain. Fresh produce production, handling, and marketing, as it operates in Thailand, and where exporting firms provide grower–customer interactions, is partly manufacturing and partly service. A successful operation needs to take into consideration the functional quality of the produce, the technical skills and experience of the people involved, and credentials and experience of the business operation. Each sector should have its own quality plan determined by what each wants out of the business operation. The strength of the chain is determined by its weakest link. There is an urgent need to

devise a new quality assurance system applicable under developing conditions for fresh produce in order to manage the chain effectively and to improve competitive strength of the business firms and the industry as a whole.

Quality Management Evolution and Quality System Options for Horticultural Crops

Quality management is not a new concept and neither are quality systems a new invention. A review of the history of quality management reveals five periods as follows:

- The first period was the time before the industrial revolution.
- The second period is the industrial revolution and its aftermath, which saw the beginning of mass production, the division of labour, and the establishment of military standards that become the ISO 9000 standards in the 1990s.
- The third period was the time of the Japanese quest for quality.
- The fourth period saw the awakening of the Americans to quality and a pre-occupation with the myth of Japanese quality management.
- The fifth period is where we are now, a time in which quality management permeates everyday life and global competition.

Total quality management must take into consideration the inherent characteristics, features, and function of the product, and operate under a planned quality management system in response to market-driven requirements and value process. Implementation of a quality system is influenced by the changing technical, social, and economic conditions against a background of broad trade politics and marketing policies.

It is now essential to have an appropriate quality management system as a marketing tool. A quality management system leads to increasing consumer satisfaction and market opportunities. Examples of existing quality management system options include 'good agricultural (or manufacturing) practice', 'hazard analysis and critical control point' (HACCP), ISO (International Standards Organization) 9000, and ISO 14000. Almost all quality management systems originated in the manufacturing sector, with emphasis on planned process control. There is a move worldwide for a system that complies with the

standards laid down in ISO 9000. Which system is chosen depends on the objective, needs, and policies of the operator. The complexity, cost, and amount of work required to set up and maintain a particular quality management system varies.

Most management systems have their share of critics. Most are influenced by the Western view of leadership and the ideal organisation emphasises policies, individual rights, freedom from domination, self-managed teams, division of labour, and contractual agreements. Asians have a different culture, which emphasises such things as direction, patronage, hierarchy, and obedience, and shared responsibility, lack of accountability, and trust. Most quality management systems based on manufacturing experience emphasise 'process push' and are built on a platform of performance of money, materials, machinery, methods, and labour. This is not applicable to a fresh produce industry where a different platform is needed, based on policy, plans, people, and place. There is a tendency to adhere to procedures while failing to address core activities that are vital to the fresh produce industry, such as leadership and strategic planning, which are ever changing, and supplier–customer interaction that is 'relationship push'. Quality attributes of food such as taste, flavour, and consumer feelings of satisfaction and wellbeing are intangible and subjective. Since they have no deep-rooted quality culture, many operators see the adoption of quality management into their business operations as merely a distraction or an impractical theory. In addition, businesses working under developing country conditions have somewhat different problems in adopting technology and management, social, economic, and political structures often become overwhelming obstacles.

The fresh produce industry as a whole has difficulty defining its business objective and setting up a quality system in which the interaction of services, products, processes, and people is prominent. For fresh produce for export, specified treatments or World Trade Organization 'sanitation and phytosanitary measures' (SPS) may need to be applied within a specific export/supply/demand chain from a regulatory and legislative point of view. Activities to comply with SPS requirements of specific target markets need to be incorporated into the management system.

Understanding the management principles, the implications of these international standards and requirements, and the ability to adopt and adapt pose an exciting challenge for the fresh produce industry.

Simplifying the Documentation Required for a Quality Management System for Horticultural Crops

It is against this background that the 'Quality Fruit System 2002' (QFS 2002) was developed in Thailand. The development of the system is based on the long-term association of the Thailand Institute for Scientific and Technological Research (TISTR) with the fresh produce export industry in Thailand. The development work was carried out with the financial support of the Thai Research Fund and later commissioned by the Department of Agriculture using durian as a case study. QFS 2002 focuses on assisting the horticultural export industry in achieving a valid framework for a quality management system for horticultural crops that meets the international norms while at the same time being feasible under developing conditions.

The system was developed around the principles of: simplicity; industry-focus; improvement to existing practice; and ability to be measured. The essential underlying concept of the system is based on the analytical tool of the 'plan-do-check-act' (PDCA) cycle while working in a 'total quality management' (TQM) environment within the framework of ISO 9000. PDCA permits an interaction of the Eastern and Western quality culture. It was tested in Japan from the time of the Japanese economic recovery after the World War Two and reached its zenith in the 1980s. The year 2000 version of ISO 9000 standards has been modified from the previous version to incorporate the essence of TQM in a way that is more user-friendly and has fewer interpretation problems.

A comprehensive quality management system can be overwhelming. Confused and complex documentation and paperwork has scared most people away from adopting a quality system. To reduce the amount of documentation required, using an overview approach and based on the PDCA cycle, the framework of the QFS 2002 system is presented as a table (Table 1) rather than in a descriptive quality manual. The 'P for Plan' in the PDCA cycle is used for initiating self-assessment activities by the management before the decision on a quality management system to be used is made, and to determine the objectives of the business operation and the quality levels needed to meet market-driven quality requirements. The 'D for Do' is for resource management to meet both conformance and performance qualities required of the product, to assign functional groups to carry out quality activities and the appropriateness of such activities. The 'C for

Check' and the 'A for Act' are used for ensuring that quality activities of the functional groups are effectively carried out and monitored, and to institute a review system for continual improvement.

QFS 2002 thus includes four elements:

1. commitment: analysis of customer needs and business goals, including the policy and information needed and capability to comply with customer expectations and requirements;
2. synthesis: analysis and assignment of the tasks to achieve outputs, including process flow charting and flow analysis, and planning of the operation and resource management;
3. product realisation: implementation to ensure process is effectively controlled and monitored. For fresh produce, this covers activities from purchasing, through packinghouse operations to delivery, and ensures adequacy of working environments; and
4. assessment: analysis of the constraints, consequences, and activities for continual improvement and including a review system to ensure that the 'system' is functioning. The itemised requirements under each element allow the system to be audited.

The main quality documentation is the quality plans. The example in Table 2 shows one of the most common tabulated forms in which a quality plan may be presented. This is a first-tier quality plan indicating the overall operations and the relationship and interdependency of functional groups of a packinghouse operation that exports fresh durian. The second-tier quality plans are developed for a particular activity or project or complex task. Each second-tier quality plan should indicate the acceptable quality characteristics, performance standards, or process conditions to be controlled, and the methods of control. Procedures, work instructions, and check sheets are used to support quality plans. Quality plans can also be developed and used for issues not in the production process, such as working environments, sanitation practices, or pest control measures. Quality plans must be organised and managed. More work will still be required to develop the information and guidelines for crops other than durian.

As growers and packinghouse operators become increasingly familiar with the management principles and at ease with the PDCA cycle, they can use the system for other crops, or for broader business improvement. As with any system, the descriptive details in the QFS 2002 are expected to continue to evolve and improve as more information and technology become available and to accommodate changes in the marketplace.

Table 1. Systematic diagram of the Thailand Institute for Scientific and Technological Research Quality Fruit System 2002.

Elements of quality system	1. Commitment	2. Synthesis	3. Product realisation	4. Assessment
System activities	<p><i>Analysis of the needs and goals</i></p> <ul style="list-style-type: none"> • what are the business goals? • what are customer needs in quality? • what problems need to be solved and priorities? • in the case of exports, the 'must know' and 'should know' legal, safety, and quality requirements 	<p><i>Analysis of the tasks to achieve goals</i></p> <ul style="list-style-type: none"> • use decision-making tools, e.g. PDCA, risk analysis • design product features and process, equipment type and capacity • quality plan for packinghouse operations • raw material quality plan 	<p><i>Implementation</i></p> <ul style="list-style-type: none"> • grower/supplier traceability • purchasing of fruit • fruit inspection • postharvest treatment • stocking, packing, storage • shipping transport • delivery • equipment maintenance/service 	<p><i>Analysis of the constraints and improvement</i></p> <ul style="list-style-type: none"> • review • continual improvement
TISTR QS 2002 requirements	<ul style="list-style-type: none"> • commitment to quality policy • satisfy customer needs and total quality characteristics of produce • satisfy export–import business/legislative requirements • prepare a simple organisation chart, include staff authority and responsibility, and company information data sheet • provision of backup resources (facilities, work environment) • system planning and management (milestone plan, control plan) 	<ul style="list-style-type: none"> • process flowcharting • process flow analysis • packinghouse layout and schematic diagram • PDCA brainstorming • quality plans (overall operational process and job breakdown specific activities) • grower/supplier development plan 	<ul style="list-style-type: none"> • grower/supplier approved list and identification, produce trace-back system to as far back as possible • define critical safety and quality parameters for inspection and risk analysis/assessment for priorities • produce specifications of the company or customer requirements • simple postharvest procedures such as fruit purchasing, fruit inspection, • fruit washing, postharvest treatment, packing, labeling, produce loading on container, shipping document • packinghouse pest control measures, hygienic and sanitation practice • work forms, check sheets 	<ul style="list-style-type: none"> • review of quality plans • packinghouse operation self-audit or third-party audit • customer feedback • review of product quality levels in market place • behaviour trend of competitors • personnel training

Table 2. Example of a format for a first-tier quality plan of a fresh produce exporting operation.

Originated by _____
 Approved by _____
 Date of issue _____
 Revision & date _____

Export operation										
<i>Grower/ supplier traceability</i>	<i>Sales</i>	<i>Management planning</i>	<i>Design/ development</i>	<i>Purchasing plan</i>	<i>Inspection & treatment</i>	<i>Material con- trol</i>	<i>Installation/ service/ delivery</i>	<i>Quality assurance</i>	<i>Customer/ consumer requirements</i>	<i>Regulatory authority requirements</i>
Grower/ supplier identification Produce quality, safety, liability agreement Farm quality plan & farm visit	Review of basic customer requirements Sale record	Contract planned Input/output development plan Resource management & staff training Management review	Design of process and production facilities Design of product features and functions and meet or compare with standards/ specifications Grower/ supplier development plan	Purchase control plan Grower/ supplier development plan	Fruit receiving Purchasing and fruit inspection Fruit cleaning Postharvest treatment Grading and packing	Stocking, storage, packing, transport, delivery	Equipment installation Equipment servicing Phytosanitary certificate when needed Exporting document	Witness/shelf- life test Review of fruit inspection record Review of postharvest treatment record Review of material control record Review of installation/ servicing record Review of delivery record	Produce specifications Consumer market research/ benchmarking Indicators for quality levels: consumer feedback such as statements, complaints, claims, decreasing/ increasing sales Behaviour of competition	Legislative/ regulatory requirements of destination countries Information gathering and technology inputs

A training manual consisting of eight training modules has been prepared in anticipation of increasing quality assurance activities in Thailand's agricultural export industries. The eight modules are: 1. Introduction, 2. Management briefing, 3. Choosing a quality system, 4. Quality system requirements, 5. Quality culture, 6. Baseline workshop, 7. Making quality documentation easy, and 8. Implementation. The practical training material is presented in graphic form intended as a standardised instruction manual for an introductory training course on quality management for horticultural crops. More training will be needed in the concepts of the system and to facilitate implementation.

Conclusion

A quality management system, where technology and management integrate, is an effective marketing tool in today's competitive, dynamic marketplace. Fresh produce production, handling, and marketing, as it operates in Thailand, and where export firms provide grower–customer interaction are partly manufacturing and partly service industries. Quality requirements vary depending on target markets. Business operations need to take into consideration the functional quality of the produce, the technical quality of the people involved, and the quality credentials/experience of the business operation. To adopt existing quality management systems originated from the manufacturing sectors for fresh produce is not always appropriate.

Quality assurance of horticultural produce, particularly under the developing country circumstances, needs greater flexibility in terms of control on production and marketing. The TISTR-developed QFS 2002 is based on the principles of the PDCA cycle while working in a total quality management environment. The system is presented in a tabulated form on the realisation that a quality management system for fresh produce requires a high degree of flexibility and must be simple, easy to understand, and not over-burden its users with paperwork. Quality plans are the main doc-

umentation. Procedures, work instructions, and check sheets are used to support quality plans. Training in the concepts of the system and additional information for detailed operational procedures is still required. A practical graphic training manual has been prepared.

Bibliography

- Ariffin, R., Feng, L., and Tongdee, S.C. 1995. Developing of a quality assurance system for fresh fruit in developing countries of Asia. Group project work topics — 2. In: Proceedings of the 5th International Course on Food Processing: Quality Assurance and Marketing in Food Processing Enterprises, 13 August–18 November 1995. Wageningen, Netherlands, International Agricultural Centre, 34p.
- Bounds, G., Yorks, L., Adams, M., and Ranney, G. 1994. Beyond total quality management: toward the emerging paradigm. Singapore, McGraw-Hill Book Co. International Editions, 817p.
- Dale, B.G., ed. 1990. Managing quality. UK, Prentice Hall International, 611p.
- Kotler, P. 1994. Marketing management: analysis, planning, implementation, and control, 8th ed. USA, Prentice-Hall International, 801p.
- Maccoby, M. 1997. Creating quality in the East and West. In: Quality in R&D. Selected papers from research technology management 1987–1996. USA, Industrial Research Institute, 40–42.
- Natural Resources Institute 1994. Manual for horticultural export quality assurance. Chatham, UK, National Resources Institute.
- Teboul, J. 1991. Managing quality dynamics. UK, Prentice Hull International Ltd, 157p.
- ISO/FDIS 9001 2000. Quality management systems — requirements. Final draft, 23p. Reference number: ISO/FDIS 9001:2000(E).
- ISO/FDIS 9004 2000. Quality management systems — guidelines for performance improvements. Final draft, 56p. Reference number: ISO/FDIS 9004:2000(E).
- ISO/FDIS 9000 2000. Quality management systems — fundamentals and vocabulary. Final draft, 29p. Reference number: ISO/FDIS 9000:2000(E).

Preharvest Effects on Postharvest Quality of Pak Choi

Trish Grant, John Faragher, Peter Franz, and Bruce Tomkins*

Abstract

The effects of several preharvest factors on the postharvest shelf life of pak choi were researched.

Water stress was investigated to determine whether it might prolong shelf life by hardening plants before harvest. It was examined in two ways: as sustained stress; and as intermittent stress. Intermittent water stress produced effects that were most applicable for commercial plant production. At harvest, fresh weight and relative water content did not differ between stressed and non-stressed plants. Shelf life at 10°C of whole plants was not affected by water stress even though stressed plants were greener. The implication of this result is that significant savings can be achieved, as less water can be used during production. Future experiments examining several, shorter cycles of stress might produce further information about the effects of water stress on quality and shelf life.

The influence of calcium (liquid calcium sulfate) and nitrogen (ammonium nitrate) on the growth and storage of plants was also examined. Increased calcium (Ca) alone had no significant effect on plant growth. Increased nitrogen (N) alone increased the rate of plant growth initially but late in plant development the plants suffered leaf chlorosis and necrosis. The optimal combination of Ca and N to maximise shelf life, relative water content, and intensity of green colour was high nitrogen (90 kg N/ha) and either of the two calcium rates examined (33 kg Ca/ha and 66 kg Ca/ha).

In summary, limiting water by applying an intermittent water stress and adding significant quantities of calcium in combination with nitrogen can provide savings on costs of irrigation and improve plant growth and shelf life.

PAK choi (*Brassica rapa* var. *chinensis*) has been cultivated in China since the fifth century AD. It is a versatile vegetable that is widely consumed throughout both China and Australia in a variety of ways. The aerial parts of the plant — leaves, stalks and flowering shoots — are edible. Harvesting it at various stages allows it to be used in different ways: the young juicy immature leaves can be used in fresh-cut salad mixes, while the larger more mature leaves are excellent in stir-fry dishes. However, its open leafy form makes it a highly perishable commodity, prone to wilting, yel-

lowing, and rots after harvest. In China there is little in the way of refrigerated transport or storage available to help improve shelf life. Most produce is grown relatively close to market and transport is unrefrigerated. Losses of up to 25% are common (J. Bagshaw, pers. comm. 2000) The research described in this paper was designed to investigate the preharvest factors that might be manipulated to extend shelf life. The role of plant water status on shelf life was investigated by examining the effects of both sustained and intermittent water stress on plant growth and storage. Also examined was the effect of the application of nitrogen fertilisers, alone and in combination with calcium, on subsequent shelf life.

* Institute for Horticultural Development, 621 Burwood Highway, Knoxfield, Victoria 3180, Australia.

Materials and Methods

Plants

Seedlings or transplants were grown in potting mix (Propine BJH/9321 Reverse Fines) with additional Osmocote® fertiliser (3–4 month, Scotts Australia) added at the rate of 3 kg/m³ and at an average temperature and illuminance of 20–25°C and 10–30 klx.

Sustained water stress

The trial was designed to contain 15 polystyrene boxes (Polyfoam Australia), each containing 12 seedlings (Shanghai pak choi) grown under three water stress treatments: 100 mL, 500 mL or 1000 mL per box applied every second day. Stress treatments were applied in a randomised complete block design with five blocks of the three treatments. Water was applied regularly until seedlings were 4 weeks old, after which water stress was imposed for 6 weeks.

At harvest, several physical plant parameters were assessed including fresh weight, lengths and widths of the smallest fully expanded leaf (SFEL) from the widest and longest points of the lamina and petiole, and dry weight was determined after plants or plant parts were dried at 70°C for three days or more.

Intermittent water stress

Plants used in this experiment were purchased as seedlings (Leppington Speedy Seedlings; Shanghai Pak Choi, var. 'Joi Choi') which were potted into individual 150 mm pots with the same rate of additional Osmocote® as mentioned previously. The trial was a fully randomised complete block design with 5 blocks each with 2 replicates of double pots per treatment. Plants were watered regularly for 4 weeks, after which the pots in the stress treatment were allowed to dry to approximately wilting point. Plants were maintained just above wilting point for 6 days by measuring plant weight loss daily and applying only the amount of water that had been consumed in the previous 24 hours. After the 6 days stress, plants were fully watered again for at least 10 days before harvest.

Fresh weight, dry weight, sugar content, and colour were determined as described above at harvest. Fresh weight and dry weight were also measured after 2 and 7 days of simulated shelf life at 10°C. Relative water content was calculated as:

$$(\text{fresh weight} - \text{dry weight}) \div \text{dry weight}.$$

Nutrition

Seedlings (as above) were planted 6 per polystyrene box with 1 kg/m³ rate of Osmocote® as a basal dressing. Weekly fertigation treatments (100 mL/box/nutrient) were applied. Nitrogen was applied in the form of ammonium nitrate (Pinnacle Liquid Fert®, E.E. Muir and Sons) at the rates of 0, 45 and 90 kgN/ha, and calcium was applied as liquid gypsum (calcium sulfate; GypFlo®, Debco Pty Ltd) at the rates of 0, 33 and 66 kg Ca/ha. After fertigation the plants were watered briefly to wash any nutrients off the leaves to minimise the risk of damage. Of the 6 plants/box, 4 were designated to assess shelf life and the other two were used to determine fresh weight, dry weight, relative water content, colour (as described previously), and sap nutrients. The design consisted of 5 randomised complete blocks of 9 treatments.

Sap nutrients were determined using Merkoquant strips for calcium test and nitrate test (Merk). Two plants per box were chopped up and crushed in a giant garlic crush to extract enough juice to dip the strips.

Sugar analyses

Sugar content of the pak choi plants was determined using high performance liquid chromatography. The smallest fully-expanded leaf was freeze dried and ground in a mortar and pestle before being weighed into centrifuge tubes and extracted with agitation in 5 mL of 70% ethanol and 20 mg polyvinylpyrrolidone (Sigma-Aldrich Pty. Ltd) at 85°C for 20 minutes. Tubes were then spun at 6g for 20 minutes and the resulting pellet resuspended in 5 mL 70% ethanol, and the process repeated. Pooled supernatant was reduced by evaporation to dryness, re-suspended in 1 mL of water and passed through a C18 Extract-Clean solid-phase extraction column (Alltech). The sample was eluted with MilliQ water then 20 µL was injected into a Benson BC-100 carbohydrate column (10 µm, 300 × 7.8 mm). Separation was carried out at 85°C using MilliQ water at a flow rate of 0.4 mL/min. Eluting sugars were detected by a refractive index detector (ICI LC 1240).

Leaf colour

Colour was determined using a Minolta CR-210 chromameter calibrated to the white tile and using the L, a, b colour values where L = lightness (0 = black, 100 = white), a = greenness (–a = green, +a = red) and b = yellowness (–b = blue, +b = yellow). Hue angle was further calculated to be $\arctan(a,b) \cdot 180/\pi$ (McGuire

1992). Each measure was the mean of three readings per plant.

Simulated shelf life

Heads were stored in perforated 50 μ M polyethylene zip-lock bags (Grayson Packaging) at 10°C. The end of shelf life was determined to be when the head became inedible, either as a result of yellowing, wilting, or postharvest rots. The most common cause was rots.

Figures

The error bars on Figures 1–9 indicate $\pm 1/2$ least significant differences.

Results

Sustained water stress

Sustained water stress produced plants that were smaller, had fewer leaves (Figure 1), and contained relatively less water than the well-watered treatment (Figure 2).

The smallest fully expanded leaf (SFEL) also had a lower water content in the stressed than in the well-watered treatment (data not shown). Petiole and lamina width and length were all reduced by sustained water stress (data not shown). Water stressing plants to this extent would not be practical as the outer leaves of these plants were so dry as to make the plant unmarketable. It would appear that the plant sacrifices the outer leaves in order to provide enough water to maintain the inner growing point.

Intermittent water stress

The second method used to investigate the effects of water stress on pak choi physiology was to impose an intermittent stress during the growth cycle.

Intermittent stress is more applicable and practical to apply in the field than sustained stress. A single cycle of intermittent stress for 6 days produced plants that were not significantly different from well-watered controls with respect to fresh weight (data not shown) or relative water content, either at harvest or throughout shelf life (Figure 3).

Stressed plants did not differ from controls in how much sugar was accumulated, nor in the proportion of either sucrose, glucose, or fructose (Figure 4). Shelf life was not significantly longer for stressed plants than non-stressed plants (Figure 5) but plants were

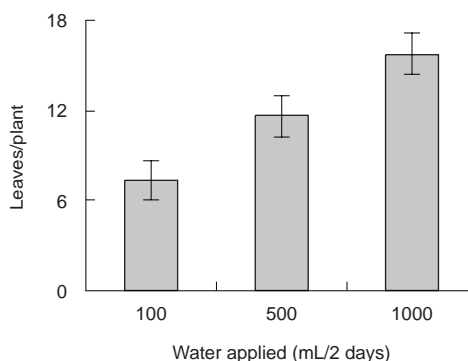


Figure 1. Effect of sustained water stress on leaf number of pak choi.

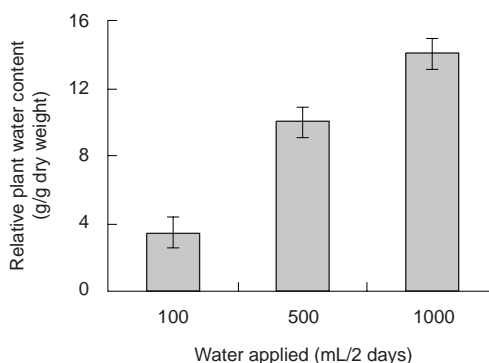


Figure 3. Effect of intermittent water stress on relative water content of pak choi at harvest and throughout simulated shelf life at 10°C.

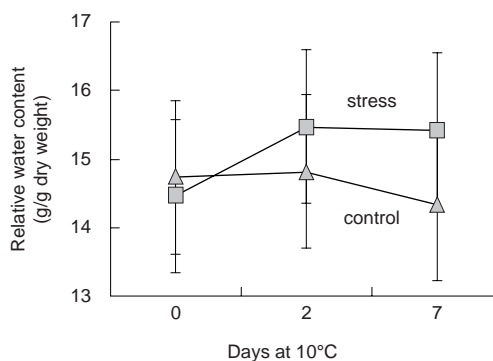


Figure 3. Effect of intermittent water stress on relative water content of pak choi at harvest and throughout simulated shelf life at 10°C.

greener, as reflected by hue angle (Figure 6). Observation would suggest that green colour was particularly dark at the end of the stress period but had diminished markedly by the time measurements were taken at har-

vest. Plants had, by that time, been well watered for a minimum of 10 days. If plants were harvested after they had fully recovered from the stress but before the colour differences diminished, shelf life might be enhanced. This experiment showed that a single cycle of water stress did not drastically reduce yield, nor did it improve shelf life, but it did result in greener plants. Future work should determine whether this colour change also reflects a change in nutritional value. The implications of intermittent water stress in production terms are significant as savings can be made by reducing the amount of water that is applied to a crop. It should be pointed out that the stress period was a proportionally large part of the growing time of the plant and it is remarkable that it did not cause larger differences in fresh weight and quality.

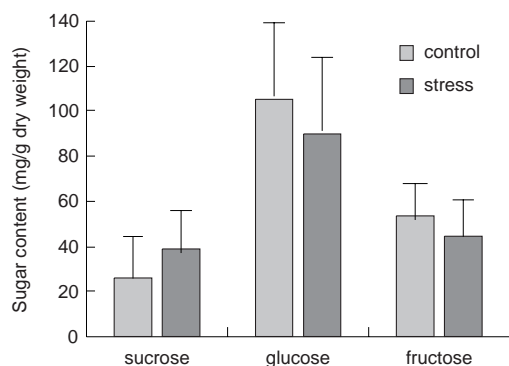


Figure 4. Effect of intermittent watering on sugar composition of pak choi.



Figure 5. Effect of intermittent watering on shelf life of pak choi.

It would be interesting to investigate the effects of more frequent but shorter stress periods as work by Williams et al. (1988, 2000) showed in potted roses that intermittent water stress during cultivation reduced water loss during shipping. Stomatal closure was prolonged with repeated water stress events.

Shorter periods of stress, combined with an earlier harvest when plants are noticeably greener, would be worth investigating.

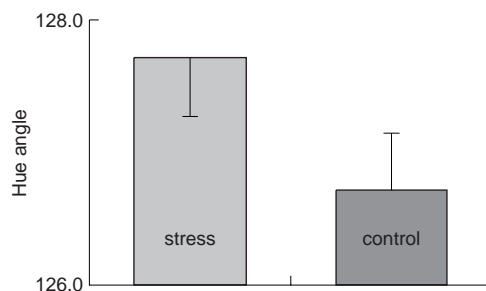


Figure 6. Effect of intermittent water stress on colour of pak choi.

Nutrition

The importance of nitrogen fertiliser for the growth of green leafy vegetables is undoubted. Nitrogen is required to promote vigorous growth but it is possible that too much vigour could result in reduced shelf life. The application of calcium in conjunction with nitrogen may strengthen cell walls and thus support vigorous growth and prolong shelf life. Experiments were designed to test this by applying three rates of calcium with three rates of nitrogen in a fully factorial trial.

Results indicate that both calcium and nitrogen are essential for normal, healthy growth. Application of calcium alone had no significant effect on growth or shelf life when no extra nitrogen was applied. However, when nitrogen was applied, calcium was essential for the maintenance of healthy growth.

Shelf life was significantly increased by fertilising plants with the high rate of nitrogen (90 kgN/ha) combined with a calcium application rate of 33 kg/ha (Figure 7). There was no significant effect on shelf life of either calcium applied without nitrogen or nitrogen applied without calcium. In the treatment that combined zero calcium with 90 kg/ha nitrogen, growth was vigorous and healthy up until 2 weeks before harvest, at which point leaves became severely necrotic and chlorotic, and heads were largely unmarketable (Figure 8).

Colour (as measured by hue angle) was maximised by the addition of N fertiliser (Figure 9). There was no difference in colour between 45 kgN/ha and 90 kgN/ha but both these rates produced plants which were greener than if no N was added. However, when the nitrogen rate is high, Ca is required in order for colour to be maintained. When high nitrogen (90 kg/ha) was

added without additional Ca then, as mentioned above, plants became chlorotic. The addition of Ca without N did not increase green colour.

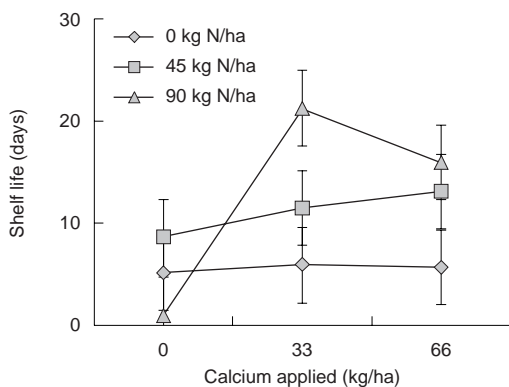


Figure 7. Effect of calcium and nitrogen fertiliser on shelf life of pak choi.



Figure 8. Effect of calcium and nitrogen on growth of pak choi. Left is high nitrogen and high calcium, right is high nitrogen and low calcium showing chlorosis and necrotic lesions on the plants.

Relative water content was not affected by calcium application when no nitrogen was applied (Figure 10). Like colour, the main increase in relative water content came with application of nitrogen fertiliser and did not increase significantly when N was doubled. However, when N was high, Ca was required to maximise relative water content.

Discussion

Sustained water stress at the level tested here is not practical, as resulting losses in plant quality and yield

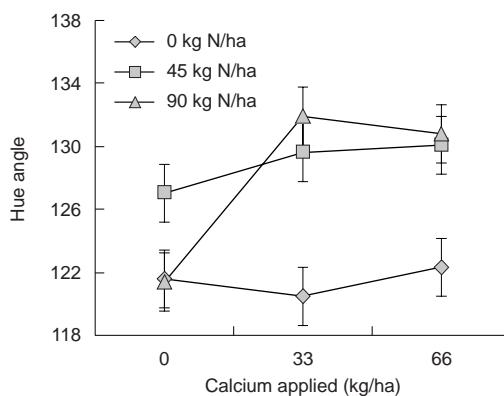


Figure 9. Effect of calcium and nitrogen fertiliser on hue angle of pak choi.

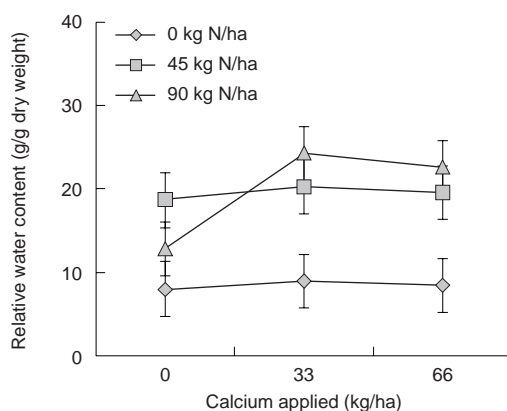


Figure 10. Relative water content of pak choi grown with different rates of nitrogen and calcium fertiliser.

are too large. Application of intermittent water stress produced some interesting results, which could be useful in the field. The hypothesis was that water stress may induce a hardening (e.g. stomatal closure or cuticle thickening) that may significantly increase shelf life by reducing postharvest water loss. This would be beneficial only if yield and quality were not affected. (Williams et al. 1988, 2000). Our experiment demonstrated the high degree of adaptability of plants to stress conditions and illustrated that water need not be applied in excess to maximise yields. In fact, intermittent stress produced considerably greener plants without a significant reduction in relative water content or fresh weight. It is anticipated that several shorter cycles of stress may further improve shelf life by closing stomata more permanently. Fertigation

with nitrogen and calcium produced larger, greener plants, which had a longer shelf life. The application of nitrogen must be combined with the addition of calcium as plant growth can eventually be limited by nitrogen application alone. Application of nitrogen should not be too high, as optimal effects are achieved by relatively low rates. In summary, pak choi growth and shelf life appear not to suffer from some intermittent water stress and benefit from the application of conservative quantities of N with additional calcium.

References

- McGuire, R.G. 1992. Reporting of objective colour measurements. *Hort Science*, 27, 1254–1255.
- Williams, M.H., Rosenqvist, E., and Buchhave, M. 1988. Response of potted miniature roses (*Rosa × hybrida*) to reduced water availability during production. *Journal of Horticultural Science and Biotechnology*, 74, 301–308.
- 2000. The effect of reducing production water availability on the post-production quality of potted miniature roses (*Rosa × hybrida*). *Postharvest Biology and Technology*, 18, 143–150.

Chinese Cabbage Management before and after Harvest

Andreas Klieber, Kerry Porter, and Graham Collins*

Abstract

Chinese cabbage (*Brassica rapa* var. *pekinensis*) cv. 'Yuki' was grown, harvested and stored under various conditions to optimise postharvest quality. Transient water stress, achieved by rewatering when tensiometer readings declined to -35 to -40 kPa (no stress), -55 to -60 kPa (medium stress) or -75 to -80 kPa (high stress), had no effect on water status, trimming loss, quality or sugar levels; neither did the time of day at which harvesting occurred, from dawn to dusk, influence these parameters. This was because of the protection provided by the wrapper and coarse outer leaves; temperature fluctuations were 150% higher in those leaves than the insulated head. Minor cooling delays of 0.5 hours in the field did not affect quality.

Postharvest changes in heads stored for up to 3 weeks at 20°C or up to 9 weeks at 0°C or 2°C were mainly a result of water loss and microbial infections on outer leaves, the base, and wound sites, resulting in trimming losses. Chlorophyll breakdown was a minor issue, as inner leaves contain little and outer leaves also generally showed other deteriorative symptoms as well. Postharvest disorders occurred, especially patchy papery necrosis (PPN). PPN was identified as a form of chilling injury; its incidence was most severe during storage at 0°C, little was found at 2°C, and none at 20°C. Injury induced through compression (under 3 kg for 42–48 hrs), dropping (twice from 50 cm), and repeated trimming, compared with not handled heads, induced little product failure such as splitting and did not produce any observable physiological differences. The only exception was that repeatedly trimmed heads produced much less ethylene, as senescing and rotting outer leaves were not present. However, this did not result in different quality or reduced trimming losses at the end of 9 weeks storage.

CHINESE cabbage (*Brassica rapa* var. *pekinensis*) is a relatively non-perishable crop that can be stored for 3 months or more under ideal conditions (Schouten 1985; Wang 1985). The respiration rate of Chinese cabbage is considered low (Zong and Morris 1986). Under long-term storage or unfavourable conditions, Chinese cabbage is prone to ethylene-induced leaf abscission (Wang 1985), petiole spotting, also known as gomasho, black fleck, or vein necrosis (Phillips and Gersbach 1988; Mathiassen 1986), rots (Peters et al. 1986; Pelleboer and Schouten 1984), and weight loss (Yong et al. 1993).

The final quality and storage life of Chinese cabbage is heavily dependent on a number of growing practices and selection of appropriate cultivars. The

main growing-related disorders are tipburn, bolting, and gomasho (Daly and Tomkins 1997). Control of these disorders is in part by using resistant varieties and in part by using appropriate cultural techniques (Daly and Tomkins 1997).

Bolting is avoided by not growing in low temperatures, using plastic row covers (Daly and Tomkins 1997), or maintaining above 18°C the temperature at which seedlings are raised (Wiebe 1990). Gomasho is promoted by high nitrogen (N) application (especially ammonium nitrate) in the field and may be reduced by harvesting in warm weather when N turnover is highest (Mathiassen 1986). It is also exacerbated by a pH of 8 or above, high levels of phosphorus (Phillips and McKay 1989) and high tissue copper and low tissue boron levels (Phillips 1990). However, Phillips and Gersbach (1988) found that cultivar selection may have a bigger effect, as some cultivars, e.g. 'Kasumi 11', 'Hong Kong', and 'Orient Express', were very

Department of Horticulture, Viticulture and Oenology,
University of Adelaide, Waite Campus, PMB 1, Glen
Osmond SA 5064, Australia.

sensitive to this disorder, while others, e.g. 'China Pride' and 'Treasure Island', showed good tolerance at low temperatures. Proper storage conditions, as outlined below, are also important to retard the development of symptoms.

Tipburn is caused by poor translocation of calcium into the young, inner leaves and is associated with rapid growth and high transpiration through the outer leaves that reduces root pressure loading of calcium into the inner leaves (Daly and Tomkins 1997). It may also be caused by the developing floral parts after vernalisation competing for the available calcium (Pressman et al. 1993). Soluble calcium content was reduced in plants that were root growth restricted (Aloni 1986). Increased N fertilisation, regardless of type, reduced tipburn in one study (Vavrina et al. 1993), but Tao et al. (1986) found that ammonium toxicity may be responsible for tipburn when applied during head formation (Anon. 1984). Control of tipburn can be achieved also by increasing the humidity at night by spraying water or by using plastic covers (Guttormsen 1985); this reduced outer leaf transpiration and allowed increased calcium accumulation of the inner leaves. Foliar application of calcium did to some extent limit this disorder (Pressman et al. 1993), but this was not found in other studies (Borkowski et al. 1993, 1994). Repeated applications of calcium and naphthalene acetic acid (Wen et al. 1991) or daminozide (Aloni et al. 1986; Pressman and Aviram 1986) were other control methods that were found to be successful.

Water status is also an important quality-determining factor for Chinese cabbage. Chinese cabbage had a better yield and less tipburn with more frequent irrigation (Suh et al. 1987; McKay and Phillips 1990), so long as the irrigation water was not overly saline (McKay and Phillips 1990). Heat tolerance of Chinese cabbage was found to be related to better water uptake through a more vigorous root system and thicker leaves (Kuo et al. 1988). Water status at harvest may also play an important role, but no information is available as to what time of day it is best to harvest is. While turgid leaves at harvest are desirable (Daly and Tomkins 1997) and water loss should be reduced by harvesting on a cool day (Nguyen 1992) sugar levels in komatsuna, another *Brassica* crop, are higher in the afternoon. This increased sugar content may be important for prolonged storage as nutrient reserves in leaves are generally low and varieties of lower storage quality contained lower soluble solids than better storing ones (Wang 1993).

After harvest, a storage temperature of -1 to 0.5°C is generally recommended for Chinese cabbage (Mathiassen 1986; Peters et al. 1986). However, Apeland (1985) found a form of chilling injury, brown midribs, after 45 days storage at 0°C . Midrib browning was reported to be associated with increases in levels of ACC, an ethylene precursor (Wang and Ji 1988). Some varieties, for example 'WR Green 60' and 'Tip Top', were seriously to moderately affected, whereas Treasure Island was unaffected. Kramer (1989) found that 12 weeks storage at 0°C was possible for Chinese cabbage, and that the hybrid Kingdom 65 best for storage at 0 – 1°C for 14 weeks. However, a maximum of 6 weeks storage in low temperatures without controlled atmospheres was recommended by Mertens (1985). Varietal differences are the most likely cause of the observed differences in behaviour.

Chinese cabbage should be stored in 98–100% relative humidity (Hansen and Bohling 1981; Mathiassen 1986), for example in perforated polyethylene bags (Yong et al. 1993; Edmond et al. 1995).

We therefore examined the effect of pre- and post-harvest factors that had not been sufficiently researched: water stress during growth; time of day of harvest; delays in cooling; senescence processes during storage; and injury during handling.

Materials and Methods

Water stress during growth

Transient water stresses, mimicking insufficient irrigation, were applied to Chinese cabbages during growth and heading stages. Chinese cabbages cv. 'Yuki' were grown at the Ovens Research Centre, Victoria, Australia on three adjacent raised beds, representing replicates, each with three separate water stress plots with equal numbers of cabbages. After seedling establishment, soil moisture levels were monitored using tensiometers and cabbages were irrigated when readings were -35 to -40 kPa for 'no stress', -55 to -60 kPa for 'medium stress', or -75 to -80 kPa for 'high stress'. All treatments were fully irrigated 24 hours before harvest. Cabbage heads were then harvested on 5 May 1999 in early to mid morning, placed in lined, waxed cardboard cartons in the field and taken immediately to a coolroom. One head per treatment per replicate was sampled for relative water content, and the remaining 12 stored in the coolroom at 0°C overnight before transport, within 2 days, to the Adelaide University Waite Campus, South Australia,

at 2°–8°C. They were stored at 0°C for up to 9 weeks, and assessed at regular intervals as outlined below.

Time of day of harvest and cooling delay

Chinese cabbage cv. 'Yuki' was grown at the Ovens Research Centre, Victoria, Australia on three adjacent raised beds, representing replicates, containing two rows of approximately 120 plants each that were divided into 10 plots. The crop was harvested on 4 May 1999, with each of the 10 plots allocated to a randomised complete block design of five harvest times — dawn, mid-morning, midday, mid-afternoon and dusk — by two holding periods — cool immediately and hold in-field for 30 minutes. Harvested heads were packed into waxed cardboard cartons fitted with polyethylene liners in the field and then transported at the designated time to a coolroom set at 0°C for cooling and overnight storage.

One head from each treatment was sampled to determine the relative water content. The remaining 12 heads were then transported to Adelaide where, on arrival, they were placed in separate perforated polyethylene bags and stored in cartons at 0°C. Three cabbages per replicate from each of the 10 harvest treatments were removed from storage for postharvest evaluation at intervals of 0, 3, 6, and 9 weeks.

Head temperatures in the field at various points inside and outside mature Chinese cabbage heads were measured using temperature data loggers. Three Chinese cabbage plants cv. 'Yuki' of uniform size and maturity, and situated adjacent to each other, were selected in a crop grown at Virginia, South Australia. Each cabbage plant was fitted with five temperature data loggers (Tinytalk Temperature Datalogger, Gemini Data Loggers, UK), with stab probes attached. Two probes were placed inside the cabbage head, one at the base and one in the centre. A third probe was placed under the leaves at the top of the head, while another was placed inside the midrib of a wrapper leaf, and one was suspended above the ground in the shade of the Chinese cabbage plant. Measurements were taken from 11 to 16 May 2000.

Senescence processes

A crop of 'Yuki' was grown at Virginia, South Australia under commercial practices and 60 heads harvested on 29 and 31 May and 2 June 2000 as three replicates. Harvested heads were placed into unlined, waxed cardboard cartons in the field and transported to Adelaide University Waite Campus within 2 hours. There, heads were placed in separate, perforated

plastic bags, randomly allocated to a storage temperature treatment, 0, 2 or 20°C, and storage period, 0, 1, 2, 3, 6 or 9 weeks, and stored in cartons in coolrooms with 5 heads per treatment unit. Assessment during storage included respiration rate, ethylene production, weight loss, trimming loss and quality score (appearance, disorders). The incidence (percentage of heads affected) and severity score (1 = none; 4 = severe) of patchy papery necrosis (PPN) also was recorded. The zero time assessment was carried out 24 to 72 hrs after heads were placed into coolrooms to allow them to cool before taking temperature-sensitive measurements of respiration and ethylene production.

Injury during handling

A crop similar to that used to assess senescence processes was harvested on 19, 23, and 26 June 2000, as three replicates, and all heads stored at 2°C. In the laboratory, sound heads were subjected to wound stresses before storage. These included, for each storage period (0, 3, 6 or 9 weeks) dropping the heads inside plastic bags twice from a height of 50 cm, compression of heads (in plastic bags) between a wooden board and the concrete floor with the equivalent of 3 kg per cabbage for 42–48 hours, or trimming of the 2–3 outermost leaves as close to base as possible. The wounding was designed not to cause physical failure, but to measure physiological changes induced by stress. The control was not stressed before storage. Postharvest assessments were as for the experiment above, with respiration and ethylene assessments done before and after wound treatments were applied, as well as at the end of each storage period.

Postharvest evaluation

Relative water content was determined on three leaves from each head by weighing them before (fresh weight) and after (dry weight) drying in a fan-forced oven set at 60°C; the relative water content was calculated by dividing the difference between the weights by the fresh weight and expressing the result as a percentage.

Respiration and ethylene production rates were measured using flame-ionisation gas chromatography. Heads were weighed and placed into sealed 15 L plastic buckets for 1 hour (20°C) or 24 hours (0° and 2°C), a 1 mL gas sample was analysed, and headspace volume determined according to a weight-to-volume curve.

Upon removal from cool storage, cabbages were weighed, trimmed of senescing or damaged leaves to achieve a marketable standard, and then reweighed.

Trimming loss was calculated by subtracting the trimmed weight from the pre-trimming weight and recorded as a percentage of the pre-trimming weight.

The location and severity of visual symptoms of senescence (yellowing, browning), rotting, and of pre- and postharvest disorders (tipburn, gomasho, pest damage, PPN) were recorded. Also, an overall quality score of the Chinese cabbages was recorded according to their symptoms, ranging from 0 (good) to 3 (acceptable) for marketable quality, to 4 (below acceptable) for unmarketable quality.

Levels of sucrose, glucose and fructose in Chinese cabbage samples were determined using an enzymatic assay technique. Four samples, an outer, middle and inner leaf, and the core, were frozen to -80°C , freeze-dried and then ground into a homogeneous powder. Samples were deproteinised by adding 640 μL 0.6 M HClO_4 to 5 mg of sample, mixing and then adding 360 μL 2 M KOH. The mixture was centrifuged for 15 minutes at 17,000 g and 750 μL of the resulting supernatant was adjusted to pH 8.0 using 0.5 M KOH and then diluted with an equal volume of milliQ water. The extract (50 μL) was used in an assay technique based on the Boehringer Mannheim Sucrose/D-Glucose/D-Fructose Enzymatic BioAnalysis kit (Catalogue No. 716260). The levels of sucrose, glucose, and fructose (mg/g dry weight) were estimated from the absorbency of NADPH at 340 nm measured using a Varian Cary 1 UV-Visible Spectrophotometer (Varian Australia, Mulgrave, Victoria).

Data analysis

All numerical data were analysed for variance using Genstat 5, 4th Edition for Windows (Lawes Agricultural Trust, IACR, Rothamsted). Differences between treatments were determined using least-significant difference (LSD) at the 5% level.

Results and Discussion

Water stress during growth

The water stress treatments during growth did not affect the postharvest physiological responses, harvested yield, or quality (Figure 1) of the Chinese cabbages. No differences in weight loss, trimming loss, or energy substrate levels were found, and water status was very similar, with the relative water content at harvest ranging from 94.4–94.9%.

This indicates that Chinese cabbage heads recovered from the transient water stresses when they were rewa-

tered. The identical yield and energy substrate levels of the harvested heads suggest that Chinese cabbages were still able to photosynthesise effectively. In addition, weight loss after harvest was comparable, indicating that water stress did not induce any permanent water stress responses such as cuticle thickening or modified stomatal responses. It is not clear as yet whether the ability of Chinese cabbages to withstand temporary water stress is linked to the wrapper leaves being preferentially affected compared with the rest of the head, as documented below for the response to time of day of harvest. An alternative explanation is that Chinese cabbages grew a stronger root system in response to the water stress to allow more efficient water uptake (Kuo et al. 1988). As heads were rewatered before harvest, the water status did not vary at harvest.

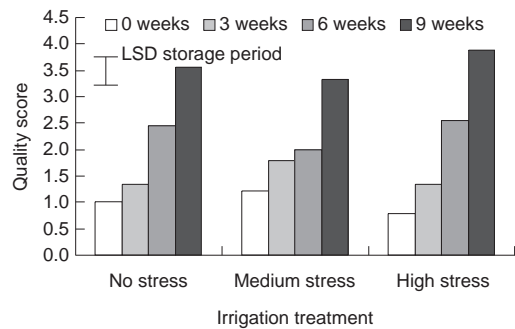


Figure 1. Quality score of Chinese cabbage cv. 'Yuki' transiently water stressed during growth after storage at 0°C . A score of 0 was the best quality and above 3 was considered unmarketable. Means of 12 heads each in three replicates are shown. Irrigation treatments did not influence quality ($P > 0.05$), and the least significant difference (LSD) ($P = 0.05$) for storage periods is shown.

Time of day of harvest and cooling delay

The time of day of harvest (dawn, midday, dusk) did not influence quality (e.g. trimming loss) or storage life of Chinese cabbage (Table 1). No trend was found in water status or energy substrate levels (Figure 2) with harvest time. A delay in cooling harvested cabbages, left in the field for 0.5 hours at temperatures ranging from 6.1°C to 20.3°C , also had no influence on these parameters (Table 1).

This result was not expected, given that leaf turgor, generally highest in the morning, is desirable for good

storage of Chinese cabbage (Nguyen 1992; Daly and Tomkins 1997). On the other hand, sugar levels in komatsuna, another *Brassica* crop, are higher in the afternoon, and have been linked to improved storage (Wang 1993). However, we found no variation of water status or energy substrate levels throughout the day and subsequent storage was not affected. This can be explained by the observations of temperature effects on Chinese cabbages in the field.

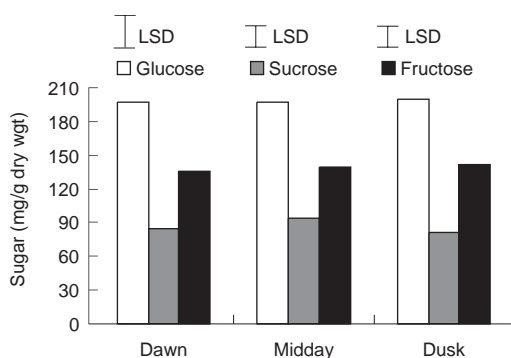


Figure 2. Average sugar levels at harvest of Chinese cabbage heads cv. ‘Yuki’ harvested at different times of the day. Means of four locations in 12 heads in each of three replicates are shown. The least significant difference (LSD) ($P = 0.05$) for each sugar is shown.

Temperature fluctuations at various points inside and at the surface of mature Chinese cabbage heads in the field (Figure 3) show that the inside of the head was protected or insulated, while the wrapper and outer leaves were most affected by temperature extremes. These therefore are also most likely to be affected by temperature-induced changes in water status and of the respiration/photosynthesis balance. Because the wrapper and some of the outer leaves are trimmed at

harvest, only that part of the head that had been protected was stored.

Temperatures in the field and metabolic rates were relatively low and heads were protected from water loss by packaging, ensuring that a minimal delay in cooling usually experienced in commercial practice had no impact on postharvest life. Also, owing to their bulk and packaging, heads took overnight to cool to 0°C, so that the 0.5 hour delay in the field did not affect their cooling to any great extent.

Senescence processes

Chinese cabbage cv. ‘Yuki’ had low rates of respiration and ethylene production, especially at low temperatures, and weight and quality fell slowly but steadily during storage. This is the reason for its relatively long storage life. There were large differences in the rate of quality loss between 20°C and the low temperatures in all assessments, but no differences between 0°C and 2°C.

The first visible sign of senescence was the breakdown of chlorophyll, leading to yellowing of the edges of the outer leaves. This was first observed after 2 weeks at 20°C, but not until 6 weeks at the lower temperatures. This was not as serious an issue as for highly chlorophyllous leafy vegetables; the inner leaves of Chinese cabbage contained little chlorophyll. In any case, the outer leaves affected would have been trimmed off owing to the development of rots.

Rotting caused by microbial infection, mainly of outer leaves, the base, and other exposed wound sites, usually follows yellowing. Rotting is typically the main reason for reduction in quality and loss of saleable weight as a result of trimming.

The presence of postharvest disorders such as gomasho (we used a resistant cultivar) and PPN may also contribute to quality loss. PPN is a serious postharvest disorder and was described by Daly and

Table 1. Trimming loss and quality score after 9 weeks of storage at 0°C for Chinese cabbage cv. ‘Yuki’ harvested at different times of the day and held in-field for different periods before cooling.

	Harvest time			Holding period	
	Dawn	Midday	Dusk	0 hours	0.5 hours
Trimming loss (%)	22.6a	21.3a	21.8a	21.5a	22.1a
Quality score ^a	2.2a	1.8a	2.0a	1.9a	2.2a

^a Scores between 0 and 3 denote good (marketable) quality and scores >3 denote poor (unmarketable) quality. Values are means of 12 heads in each of three replicates and different letters in rows for each factor denote significant difference using least significant differences ($P = 0.05$).

Tomkins (1997); however, what causes it has previously not been elucidated. Our cultivar 'Yuki' was susceptible, and severity and incidence (Figure 4) were high after storage at 0°C, but much less occurred at 2°C, and none at 20°C. This suggests that PPN is a form of chilling injury. Previously, a temperature range of -1 to 0.5°C has been recommended for storing Chinese cabbage (Mathiassen 1986; Peters et al. 1986), but Apeland (1985) found a form of chilling injury termed 'brown midribs' after 45 days storage at 0°C. For chilling-injury-susceptible cultivars like

'Yuki', storage temperatures above 2°C are needed. Different cultivars of Chinese cabbage, if they are susceptible to chilling injury, seem to be susceptible to different forms of the phenomenon.

Injury during handling

Chinese cabbage was not affected by any of the wounding treatments applied. The trimming, dropping, and compression treatments applied, were aimed at mimicking typical stresses experienced during Aus-

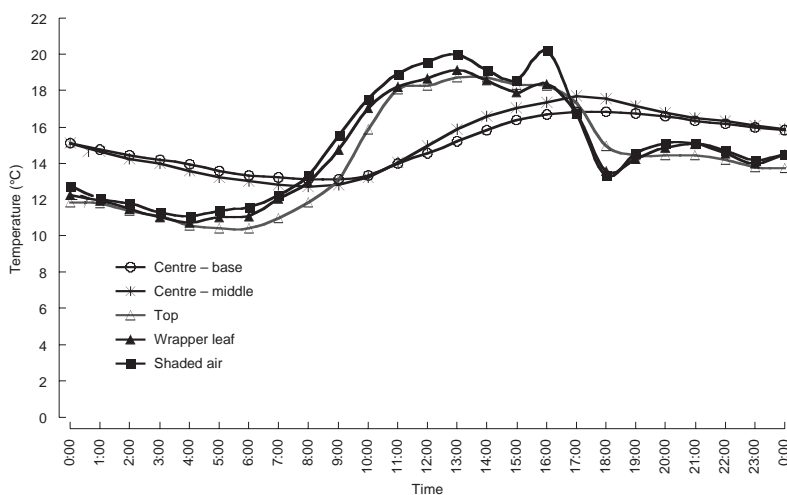


Figure 3. Temperature fluctuations over a 24-hour period at various positions inside and outside mature Chinese cabbages heads cv. 'Yuki' growing in the field. Minimum and maximum temperatures in the region for the same period, as recorded by the Bureau of Meteorology, were 13°C and 22°C, respectively. Values are means of data from three heads.

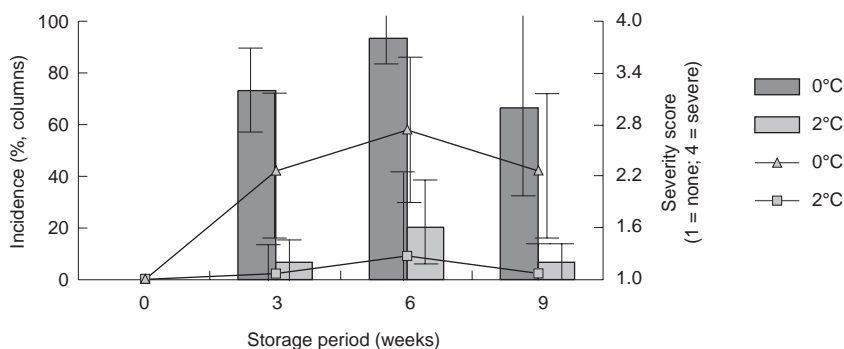


Figure 4. Incidence and severity of patchy paper necrosis (PPN) in Chinese cabbage cv. 'Yuki' during low temperature storage. Means \pm standard deviation of 12 heads each in 3 replicates.

tralian export conditions, and only in very few cases did they lead to product failure such as splitting of leaves. The stress induced by the treatments did not result in any obvious physiological change, quality differences, or final trimming losses.

The only difference found between treatments was that heads that were trimmed regularly had lower ethylene production at the end of storage. The trimmed heads consistently produced about 0.003 μL of ethylene/kg/hour, while the other treatments increased to about 0.01 μL /kg/hour after 6–9 weeks of storage. This shows that the outer leaves that were not trimmed produced more ethylene than the rest of the head, related to the earlier occurrence of senescence and disease on the outer leaves, as described above. The insides of the cabbage heads were not affected by this increase in ethylene production.

Conclusion

Chinese cabbage cv. 'Yuki' is a relatively resilient crop in the field, as it manages to avoid problems linked to transient water stress, and is not affected by the time of day at which it is harvested. This is linked to the differential behaviour of the wrapper leaves that are trimmed off at harvest, compared with the protected rest of the head. Also, short cooling delays did not affect postharvest outcomes, as heads were protected from water loss and did not experience excessive temperatures.

After harvest Chinese cabbage cv. 'Yuki' enjoys a long storage life, because it has a low metabolic rate, but eventually some yellowing and, in particular, microbial rots lead to the degradation of the outer leaves. These can be trimmed off, so that after 9 weeks the inner head is still marketable. Nevertheless, this can lead to saleable weight losses of over 20% and trimming is an additional handling cost. Also, various forms of chilling injury of Chinese cabbage need to be considered for susceptible cultivars. 'Yuki', for example, should be stored above 2°C. Mechanical stresses below those that cause obvious product failure, e.g. splitting, as are experienced in handling systems like in Australia where heads are well packaged, did not affect postharvest outcomes.

References

- Aloni, B. 1986. Enhancement of leaf tipburn by restricting root growth in Chinese cabbage plants. *Journal of Horticultural Science*, 61, 509–513.
- Aloni, B., Pashkar, T., and Libel, R. 1986. The possible involvement of gibberellins and calcium in tipburn of Chinese cabbage: study of intact plants and detached leaves. *Plant Growth Regulation*, 4, 3–11.
- Anon. 1984. Effect of time, form and concentration of nitrogen application on Chinese cabbage tipburn. Asian Vegetable Research and Development Center Progress Report 1984, 385–393.
- Apeland, J. 1985. Chilling injury in Chinese cabbage *Brassica campestris pekinensis* (Lour) Olsson. *Acta Horticulturae*, 157, 261–270.
- Borkowski, J. and Szwoonek, E. 1993. Effect of temperature and spraying with calcium nitrate on health of Chinese cabbage, yield and nitrate content. *Biuletyn Warzywniczzy*, 40, 15–24. (Abstract)
- Borkowski, J., Szwoonek, E., Babik, I., and Rumpel, J. 1994. The effect of temperature on Chinese cabbage tipburn and its control by calcium nitrate or citric acid. *Acta Horticulturae*, 371, 363–369.
- Daly, P., and Tomkins, B. 1997. Production and postharvest handling of Chinese cabbage. Rural Industries Research and Development Corporation (RIRDC), Barton ACT, Australia. RIRDC Research Paper 97/1, 35p.
- Emond, J.P., Boily, S., and Mercier, F. 1995. Reduction of water loss and condensation using perforated film packages for fresh fruits and vegetables. In: Kushwaha, L., Serwatowski, R., and Brook, R., ed., *Proceedings of a conference held in Guanajuato, Mexico, 20–24 February 1995*. St Joseph, Mich., USA, American Society of Agricultural Engineers, 339–346.
- Guttormsen, G. 1985. Effects of air humidity and temperature on Chinese cabbage grown in greenhouses. *Forskning og Forsok I Landbruket*, 36(2), 81–89. (Abstract)
- Hansen, H. and Bohling, H. 1981. Long-term storage of Chinese cabbage. *Acta Horticulturae*, 116, 31–34.
- Kramer, T. 1989. Breeding activities on minor crops in the Netherlands. *Acta Horticulturae*, 242, 101–105.
- Kuo, C.G., Shen, B.J., Chen, H.M., Chen, H.C., and Opena, R.T. 1988. Associations between heat tolerance, water consumption, and morphological characters in Chinese cabbage. *Euphytica*, 39, 65–73.
- McKay, A. and Phillips, D. 1990. Chinese cabbage. Department of Agriculture, Western Australia, Bulletin No. 4197, 13p.
- Mathiassen, H.P. 1986. Discolored vascular bundles in Chinese cabbage after storage. *Gartner Tidende*, 102(48), 1614–1615.
- Mertens, H. 1985. Bewaarcondities belangrijk bij Chinese kool. *Groenten en Fruit*, 41(17), 62–63.
- Nguyen, V.Q. 1992. Growing Asian vegetables. NSW Agriculture Agfact H8.1.37, 16p.

- Pelleboer, H. and Schouten, S.P. 1984. Nieuwe methode voor bewaren Chinese kool succes. *Groenten en Fruit*, 40(16), 51.
- Peters, P., Jeglorz, J., and Kastner, B. 1986. Mehrjährige Untersuchungen zur Normal- und Kühlagerung von Chinasalat. *Gartenbau*, 33(10), 298–301.
- Phillips, D. 1990. Chinese cabbage research pays off. *Good Fruit and Vegetables*, September 1990, 26.
- Phillips, D. and McKay, A. 1989. Chinese cabbage — a crop at the crossroads. *W.A. Grower*, 26(11), 20–21.
- Phillips, D.R. and Gersbach, N.B. 1988. Factors influencing petiole spotting (gomasho) in Chinese cabbage. *Acta Horticulturae*, 247, 117–121.
- Pressman, E. and Aviram, H. 1986. Inhibition of flowering in Chinese cabbage by applying heat and growth retardants to transplants. *Plant Growth Regulation*, 4(1), 87–94.
- Pressman, E., Shaked, R., and Acran, L. 1993. The effect of flower inducing factors on leaf tipburn formation in Chinese cabbage. *Journal of Plant Physiology*, 141, 210–214.
- Schouten, S.P. 1985. Nieuw licht op het bewaren van Chinese kool. *Groenten en Fruit*, 40(33), 60–61.
- Suh, H.D., Park, S.K., and Kwon, Y.S. 1987. Effects of amounts and intervals of irrigation on the yield of hot pepper, radish and Chinese cabbage. *Research Reports of the Rural Development Administration*, 29(1), 24–29. (Abstract)
- Tao, X.Q., Zhao, H., Cheng, Q.F., and Hu, H. 1986. The effect of cultivars, fertiliser and harvest date on the storability of spring cabbage. *Acta Horticulturae Sinica*, 13(1), 42–48. (Abstract)
- Vavrina, C.S., Obreza, T.A., and Cornell, J. 1993. Response of Chinese cabbage to nitrogen rate and source in sequential plantings. *HortScience*, 28, 1164–1165.
- Wang, C.Y. 1985. Effect of low O₂ atmospheres on postharvest quality of Chinese cabbage, cucumbers, and eggplants. In: Blankenship, S.M., ed., *Controlled atmospheres for storage and transport of perishable agricultural commodities*. North Carolina State University Department of Horticultural Science, 142–149.
- Wang, C.Y. and Ji, Z.L. 1988. Abscisic acid and ACC content of Chinese cabbage during low-oxygen storage. *Journal of the American Society for Horticultural Science*, 113, 881–883.
- Wang, Y. 1993. Preliminary study on physiological mechanisms of storability differences among headed varieties of Chinese cabbage. *Journal of Shandong Agricultural University*, 24(1), 37–41. (abstract).
- Wen, F.Y., Sun, D.L., Ju, P.H., Su, Y.M., and An, Z.X. 1991. The effect of NAA on calcium absorption and translocation and the prevention of tipburn in Chinese cabbage. *Acta Horticulturae Sinica*, 18(2), 148–152. (Abstract)
- Wiebe, H.J. 1990. Estimation of the raising temperature at the time of bolting of Chinese cabbage. *Acta Horticulturae*, 267, 297–303.
- Yong, J.Y., Jin, C.J., Tag, J.C., Si, Y.L., and Un, H.P. 1993. Marketability affected by cultivars and packaging methods during the long-term storage of Chinese cabbage grown in autumn. *Journal of the Korean Society for Horticultural Sciences*, 34(3), 184–190.
- Zong, R.J. and Morris, L.L. 1986. Responses to exogenous ethylene treatment and ethylene evolution of Chinese cabbage during storage. *Acta Horticulturae Sinica*, 13(2), 113–118.

Sanitary Washing of Vegetables

**Paul G. Harrup, Robert J. Holmes, Andrew J. Hamilton, Martin I. Mebalds,
and Robert R. Premier***

Abstract

The postharvest quality of many types of vegetables can be improved by washing during preparation for market. The primary purposes of washing are to remove soil, grit, and other debris from the vegetables, eliminate undesirable microbial contaminants, and clean/sanitise wounds incurred during the harvesting process. However, these aims are not achieved when the source water is not clean or when used wash-water is recycled without appropriate treatment. Vegetable surfaces, and at times the internal tissues, can also be contaminated by human pathogens (bacteria, viruses, nematodes, and protozoans). These may derive from the use of uncomposted animal manures or contaminated irrigation and wash-water. While postharvest washing is an important control point for microbial and chemical contamination it can itself present a risk. Wash-water rapidly accumulates soft rot organisms and possibly human pathogens if it is recirculated without sufficient treatment. To minimise contamination, farmers may either use a continuous clean water source, which may be very costly, or employ an effective water treatment system using one of several classes of sanitising chemicals, heat, or UV irradiation.

The power of sanitising agents is influenced by concentration, temperature, and water pH, hardness, and organic matter content. However, the influence of these parameters on the control of specific plant pathogens and human pathogens in wash-water is poorly understood. Similarly, there is little information on the ability of sanitisers to disinfect vegetable surfaces and contact surfaces such as harvesting and handling equipment.

This paper reports experiments that demonstrate the influence of sanitation conditions on the effectiveness of sanitisers, especially hypochlorites, in water and on surfaces.

THE postharvest quality of many types of vegetables can be improved by washing during preparation for market. The primary purposes of washing are to:

- remove soil, grit and other debris from the vegetables;
- eliminate undesirable microbial contaminants; and
- clean/sanitise wounds incurred during the harvesting process.

These aims are not achieved when the source water is not clean or when used wash-water is recycled without appropriate treatment.

Soil and grit left adhering to vegetables is not appreciated by consumers. Washing can therefore enhance saleability. The soil and organic debris also harbour microorganisms including fungi and bacteria that can invade damaged tissues and cause severe rot during postharvest transport and storage (Table 1). The surface of vegetables and at times the internal tissues can also be contaminated by human pathogens (bacteria, viruses, nematodes, and protozoans; Table 2). These may derive from the use of sewage, uncomposted animal manures, or contaminated irrigation and wash water. There have been many outbreaks of disease in humans attributed to microbial contamination of fresh fruits and vegetables (Beuchat and Ryu 1997; Little et al. 1997; Tauxe et al. 1997).

* Agriculture Victoria, Institute for Horticultural Development, Private Bag 15, Scoresby Business Centre, Victoria 3176, Australia.

While postharvest washing is an important control point for microbial and chemical contamination, it can itself present a risk. Wash-water rapidly accumulates soft rot organisms and possibly human pathogens if it is recirculated without sufficient treatment. To minimise contamination, farmers either use a continuous clean water source, which may be very costly, or employ an effective water treatment system using one of several classes of sanitising chemicals, heat, or UV irradiation. The discharge of water used for washing also has the potential to spread plant disease or contaminate the environment with human pathogens and pesticides. Treatment of used wash-water before disposal may therefore be desirable.

Table 1. Major postharvest pathogens of vegetables.

Fungi and protists	Bacteria
<i>Alternaria</i> spp.	<i>Erwinia</i> spp.
<i>Botrytis cinerea</i>	<i>Xanthomonas campestris</i>
<i>Colletotrichum</i> spp.	<i>Pseudomonas</i> spp.
<i>Fusarium</i> spp.	
<i>Geotrichum candidum</i>	
<i>Mucor</i> spp.	
<i>Penicillium</i> spp.	
<i>Rhizopus</i> spp.	
<i>Sclerotinia</i> spp.	
<i>Stemphylium</i> spp.	
<i>Phytophthora</i> spp.	

Table 2. Human pathogens isolated from fresh vegetables (J. Behrsing and R. Premier, unpublished data).

Bacteria	Protozoans and viruses
<i>Bacillus cereus</i>	<i>Cryptosporidium</i>
<i>Clostridium botulinum</i>	<i>Giardia</i>
<i>Listeria monocytogenes</i>	<i>Cyclospora</i>
<i>Salmonella</i> spp.	
<i>Escherichia coli</i>	Hepatitis A
<i>Yersinia enterocolitica</i>	Enteroviruses
<i>Camphylobacter jejuni</i>	Norwalk virus
<i>Shigella</i> spp.	Rotavirus
<i>Staphylococcus aureus</i>	

Hygienic postharvest practice is an effective strategy to minimise postharvest diseases of vegetables and this is usually achieved by sanitising produce and equipment (Coates and Johnson 1996). There are many sanitisers available, but there are few objective guidelines to help determine which are the most appropriate for a particular purpose. In Australia, chlorine-

based products are the most popular for vegetable washing, and several other types of sanitisers are used for cleaning plant and equipment. The power of sanitising agents is influenced by concentration, temperature, and water pH, hardness, and organic matter content. However, the influence of these factors on the control of specific plant pathogens and human pathogens in wash-water is poorly understood. Similarly, there is a scarcity of information on the ability of sanitisers to disinfest vegetable surfaces and contact surfaces such as harvesting and handling equipment.

This paper reports experiments which demonstrate the influence of sanitation conditions on the effectiveness of sanitisers, especially hypochlorites, in water and on surfaces. It also presents data on the quality of vegetable wash-water and discusses the implications for wash-water re-use and safe discharge

Materials and Methods

Selected sanitisers

The registration and use of sanitisers in Australia is regulated by the National Registration Authority (NRA), but there are also certain sanitisers that are exempt from registration (e.g. chlorine dioxide, when generated on site). In addition, the Australia and New Zealand Food Authority (ANZFA) regulates chemical residues in foods and approves food additives and processing aids, some of which are antimicrobial compounds. Sanitisers selected for this study are either approved by ANZFA or the NRA, or have been given an exemption by the NRA.

The selected sanitisers contain the active ingredients benzalkonium chloride (QAC), bromo-chlorodimethyl hydantoin (BCDMH), calcium hypochlorite (Ca(OCl)₂), chlorine dioxide (ClO₂), and peroxyacetic acid (PAA). Other permitted sanitisers include ozone, iodine, and peroxygens. Concentrations of active ingredients in solutions of BCDMH, calcium hypochlorite, and chlorine dioxide were determined by spectrophotometry. Sanitiser concentrations are expressed as parts per million (ppm) of the active species. For hypochlorite, this is ppm of free chlorine (fac); for BCDMH, this is ppm of free chlorine equivalents (fce).

Pathogens

The following plant pathogenic fungi and bacteria were used as test organisms: *Mucor* sp., *Penicillium* spp., *Geotrichum candidum*, *Xanthomonas campestris*

pv. *campestris*, *Pseudomonas syringae* pv. *syringae*, and *Clavibacter michiganensis* subsp. *michiganensis*. *Escherichia coli*, a common indicator of faecal contamination, was selected to represent human pathogenic bacteria.

Preparation of inocula

Bacteria were maintained at 21°C on nutrient agar (NA). Cell suspensions were prepared from 3–5-day-old cultures, enumerated by absorbance (Hach 2010 spectrophotometer), and adjusted to achieve approximately 1×10^6 cells/mL. Fungi were maintained at 21°C on potato dextrose agar (PDA). Stock inoculum was prepared by washing 5–10-day-old cultures with sterile purified water, counted using a haemocytometer and adjusted to approximately 1×10^6 spores/mL.

Cell suspension tests

Sanitiser efficacy tests were adapted from the published methods of the Association of Official Analytical Chemists (AOAC 1984) and the Australian Therapeutic Goods Administration (Graham 1978). Inoculum (1 mL of cell/spore suspension) was added to 99 mL of sanitiser solutions at various concentrations. After 30, 60, 90, 120, and 240 seconds, 0.1 mL of this solution was extracted and added to a microcentrifuge tube containing 0.9 mL of deactivator solution (0.1N sodium thiosulfate and 10% v/v Ecoteric T80). The control was sterile deionised water (SDW) in place of the sanitiser and was extracted at 240 seconds only. Except where otherwise mentioned, tests were conducted at pH 6.5–7 and at $21 \pm 2^\circ\text{C}$. A sample of the reacted product (0.1 mL) was spread-plated onto NA for bacteria or PDA for fungi. The procedure was repeated 3 times for each sanitiser. Plates were incubated and colonies counted after 72 hours, except for *M. piriformis*, which was counted after 24 hours, and *C. michiganensis*, which was counted after 5 days.

Sanitisers were trialed at half, single, and double 'label' rates. All treatments were duplicated in 'dirty water' of a standard water hardness and containing 5% inactivated baker's yeast (Graham 1978). The pH was buffered at 5.5, 7.0, and 8.5 with 0.2M NaH_2PO_4 and 0.2M Na_2HPO_4 . All reactions were conducted at 4, 21, and 30°C.

Surface tests

Two substrates were used: aluminium and wood (smooth-planed *Pinus radiata* and rough-sawn *Eucalyptus camaldulensis*). Both materials were cut into 25

cm^2 coupons. Wood was autoclaved, whereas metal was surface sterilised with 70% ethanol. Metal coupons were inoculated with 100 μL of 1×10^4 cells/mL spread with a glass rod. Three coupons were placed in stainless steel trays containing 150 mL sanitiser and removed after 1, 5, and 20 minutes. The metal was direct plated onto NA or PDA plates that were flooded with 1 mL of the deactivator. Plates were air dried for 30 minutes and then incubated at 21°C. Wood coupons were inoculated with 200 μL of 1×10^4 cells/mL and pressed onto plates flooded with 2 mL of the deactivator.

Resulting colonies were counted after approximately 72 hours. Differences in the efficacy of the sanitisers were analysed by GENSTAT analysis of variance.

Vegetable wash-water quality

Source and waste-water samples were taken from a total of 17 different carrot washing facilities: 10 in Victoria, 4 in Tasmania, 2 in South Australia, and 1 in Queensland. Some properties were sampled more than once: 25 source-water and 25 waste-water samples were collected in total. All samples were tested for turbidity, biochemical oxygen demand (an indicator of organic matter), nitrates, nitrites, soluble reactive phosphorus, total coliforms, *E. coli*, and total yeasts and moulds. Aliquots were also dilution plated on PDA, MEA, and WA to isolate fungi. All fungi isolated were identified to at least genus level. Fungi that were considered potentially pathogenic were identified to species level. Selected isolates were then wound inoculated onto carrots to confirm pathogenicity.

Results

Sanitiser effectiveness in water

In clean water, reductions of 4–6- \log_{10} were achieved in less than 30 seconds at 20°C in most pathogen sanitiser combinations. *Mucor* was the most resistant organism (data not shown). In dirty water (TGA test), where kill rates were slower, increasing the concentration of sanitiser was required to achieve better than 4 \log_{10} reductions (Figure 1, *Geotrichum* and BCDMH data shown). Dirt reduced the rate of pathogen reduction at the lower concentrations of BCDMH, calcium hypochlorite, and peroxyacetic acid (Figure 2, *C. m. michiganensis* and BCDMH data shown). The performance of chlorine dioxide (2.5 ppm) was unaffected by the TGA condi-

tions. In dirty water, 6- \log_{10} reductions were achieved within 4 minutes for all organisms (except *Mucor*) at 60 ppm of hypochlorite, 2.5 ppm of chlorine dioxide, 1000 ppm peroxyacetic acid, and 10 ppm of BCDMH. Only peroxyacetic acid (1000 ppm) and chlorine dioxide (2.5 ppm) achieved greater than 4- \log_{10} reductions of *Mucor* in dirty water.

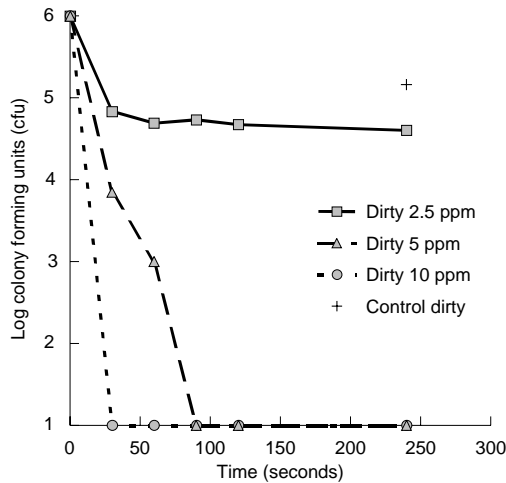


Figure 1. Effect of exposure time and sanitiser concentration on the efficacy of BCDMH (fce) against *Geotrichum candidum* in dirty water.

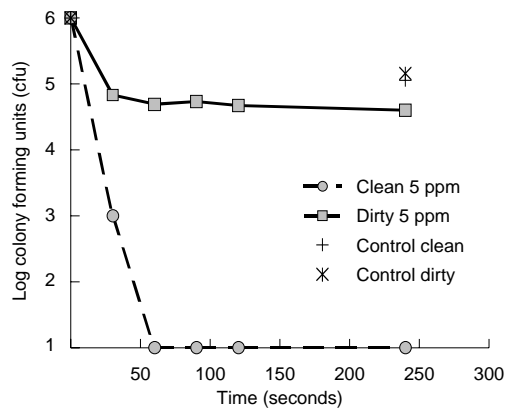


Figure 2. Effect of dirty water on the efficacy of BCDMH (2.5 ppm fce) against *Clavibacter michiganensis* subsp. *michiganensis*.

An increase in pH (from 5.5 to 8.5) decreased the performance of hypochlorites. Against *Mucor*, for example, calcium hypochlorite was almost twice as

effective at pH 5.5 than at 8.5 after 30 seconds (Figure 3). Chlorine dioxide was effective over a wider pH range and peroxyacetic acid was not significantly affected by pH over the range 5.5 to 8.5.

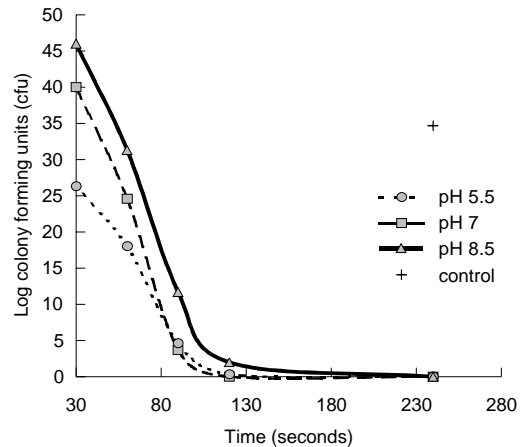


Figure 3. Effect of pH on the efficacy of calcium hypochlorite (30 ppm) against *Mucor* sp.

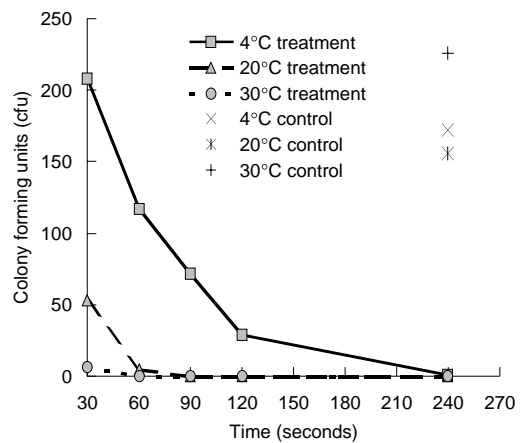


Figure 4. Effect of temperature on efficacy of BCDMH (5 ppm) against *Mucor* sp.

The efficacy of all sanitisers was reduced at low temperature (4°C). For example, the time required for BCDMH to completely kill *Mucor* was 60, 90, and 240 seconds at 30, 20, and 4°C, respectively (Figure 4).

Sanitiser effectiveness on surfaces

Peroxyacetic acid and calcium hypochlorite were the best performing sanitisers against *E. coli* on an aluminium surface, and chlorine dioxide was the poorest

(at their recommended label rates). There was no significant difference between water and chlorine dioxide (Figure 5).

Peroxyacetic acid was the only sanitiser to achieve better than a 5 log₁₀ reduction against *E. coli* on smooth *P. radiata*. There was no significant difference between chlorine dioxide and water, whereas

BCDMH, calcium hypochlorite, and benzylkonium chloride displayed similar sanitising effectiveness at 'label' rates (Figure 6).

Peroxyacetic acid was the best sanitiser against *C. michiganensis* on rough-sawn *E. camaldulensis*. Other sanitisers gave similar kill rates, with chlorine dioxide showing the lowest efficacy (Figure 7).

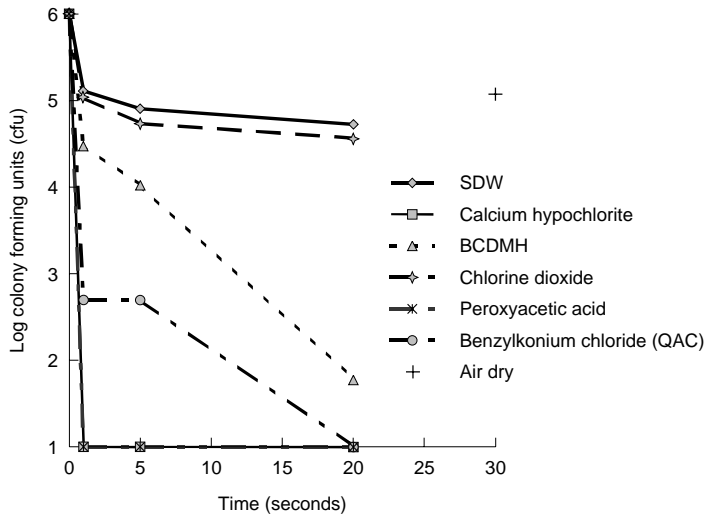


Figure 5. Efficacy of selected sanitisers against *Escherichia coli* on an aluminium surface. Sanitiser concentrations were 30 ppm fac, 5 ppm fce, 5 ppm ClO₂, 500 ppm PAA, 1000 ppm QAC.

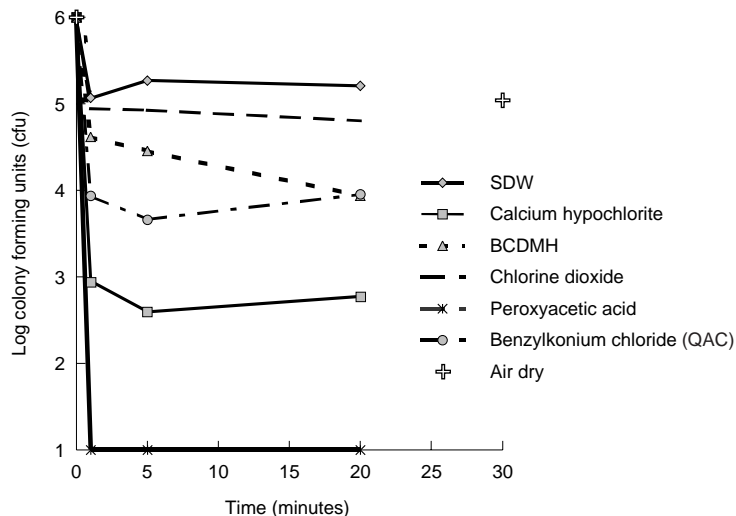


Figure 6. The efficacy of selected sanitisers against *Escherichia coli* on a smooth wood surface. Sanitiser concentrations were 30 ppm fac, 5 ppm fce, 5 ppm ClO₂, 500 ppm PAA, 1000 ppm QAC.

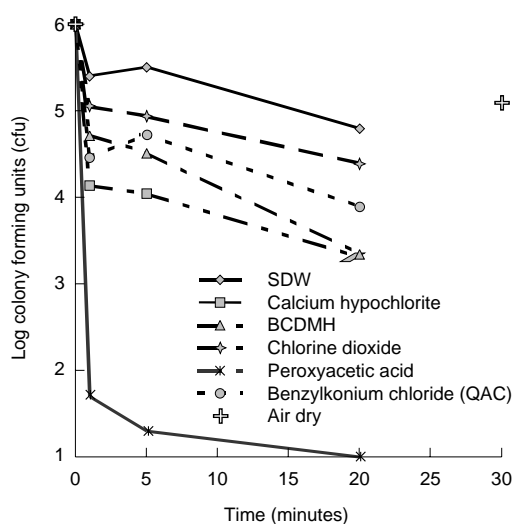


Figure 7. The efficacy of selected sanitisers against *Clavibacter michiganensis* subsp. *michiganensis* on a rough-sawn wood surface. Sanitiser concentrations were 30 ppm fac, 5 ppm fce, 5 ppm ClO₂, 500 ppm PAA, 1000 ppm QAC.

Vegetable wash-water quality

All water quality indicators deteriorated with the throughput of carrots. Concentrations of *E. coli*, yeasts, and moulds increased by an average of log₁₀, and the frequency of detection of plant pathogens also increased markedly (Table 3).

Discussion

Sanitiser effectiveness in water

In both clean and dirty water, sanitiser efficacy was proportionate to sanitiser concentration. While many sanitisers reduced pathogen counts more rapidly at double the label rate, most performed adequately at the label rate. The sanitisers that did not achieve better than 2 log₁₀ reductions in dirty water within 4 minutes contact time were calcium hypochlorite against *Mucor* and *G. candidum*, BCDMH against *Mucor*, and peroxyacetic acid against *Mucor*. As increasing contact time beyond 4 minutes would be impractical, increased amounts of sanitiser would need to be added to overcome the demand of the water hardness and organic load. Dirty water contains substances that interfere with chlorination and bromochlorination, for

example ammonia, amino acids, and calcium carbonate (Bessems 1998; White 1999). These substances create a 'chlorine demand' and only once this initial demand is met does free available chlorine or bromine (the main biocidal compound) occur. Chlorinating until the chlorine demand is satisfied is known as 'breakpoint chlorination' (Dychdala 1977). Sanitation systems that automatically deliver hypochlorites (including BCDMH) would be expected to maintain effective levels of the sanitiser above the chlorine demand of the water. Alternatively, water can be treated to reduce impurities before the sanitiser is added, or a sanitiser which is more effective in dirty water could be used. Increasing concentrations without prior water purification can prove costly and lead to increased corrosion, pollution, or worker discomfort.

Table 3. The effect of washing carrots on the quality and pathogen concentration of wash-water (Hamilton and Mebalds 2000).

Parameter	Source water	Waste-water
Turbidity (NTU)	62.5	195.2
Biochemical oxygen demand (mg/L)	7.7	29.6
Total reactive phosphorus-P (mg/L)	1.79	32.7
<i>E. coli</i> (cfu/100 mL)	44	555
Yeasts and moulds (cfu/100 mL)	41,591	418,409
<i>Alternaria alternata</i> (% of samples)	20%	52%
<i>Fusarium oxysporum</i> (% of samples)	12%	64%
<i>Mucor</i> sp. (% of samples)	16%	48%
<i>Pythium</i> sp. (% of samples)	0%	8%

Current data from researchers, manufacturers, and regulators indicate approximately 40–80 ppm of free available chlorine (from calcium hypochlorite), 5 ppm of chlorine dioxide, 80–500 ppm peroxyacetic acid, and 5–10 ppm free available chlorine equivalents (from BCDMH) were effective rates in clean wash-water.

When hypochlorites are dissolved in water they dissociate into two main compounds, hypochlorous acid (HOCl) and the hypochlorite ion (OCl⁻). The relative

abundance of each compound depends on the pH of the water. At low pH, hypochlorous acid, the more biocidal product, predominates (White 1999). In this study, as expected (Segall 1968), hypochlorite-based sanitisers were more effective at low pH. This indicates that in some instances, acidification of alkaline wash-water (e.g. using citric acid) could improve the efficiency of chlorination. At the concentrations used, chlorine dioxide and peroxyacetic acid performed well over the 5.5 to 8.5 pH range, but both are known to perform best at low pH (White 1999).

The performance of sanitisers increased at the higher temperature, as expected (Sabaa-Srur et al. 1993). Kill rates at 20°C and 30°C were similar, but at 4°C kill rates were significantly lower. This demonstrates that, in cold water e.g. in hydrocoolers, contact time needs to be prolonged.

Sanitiser effectiveness on surfaces

As expected (Gibson et al. 1996), surfaces were more difficult to sanitise than water. In some cases, compared with water, surfaces require ten times the concentration of disinfectant (van Klingeren et al. 1998). In general, sanitisers had similar performance on wood and aluminium. Peroxyacetic acid was the most effective on surfaces, whereas chlorine dioxide (which was the most effective in water tests) performed poorly. Wood was found to be the more reactive surface, and in some instances sanitisers become ineffective within 5 minutes of contact. We expect this could be overcome by increasing the sanitiser concentration, or the volume of sanitiser solution available to the surface. As with the suspension test, fungi were found to be more resistant than bacteria to sanitisers on surfaces.

The reductions of *E. coli* achieved on wood and metal surfaces (1–5 log₁₀) are similar to the 1–4 log₁₀ reductions achieved by BCDMH on broccoli after 30 minutes (P. Harrup and R. Holmes, unpublished data). Smaller reductions (1.7–2.8 log₁₀) were achieved by calcium hypochlorite on broccoli and lettuce when the contact time was 30 seconds (Behrsing et al. 2000).

The efficiency of disinfecting compounds is relative to the rate of diffusion of the active agent through the cell wall (White 1999). Therefore, the addition of suitable surfactants to reduce the surface tension on the cell wall could enhance surface sanitation (Kostenbauder 1977). This aspect deserves further study.

Vegetable wash-water quality

Carrot wash-water quality deteriorates over time and other research (Morgan 2001) found higher than normal sanitiser concentrations were required to sanitise potato wash-water because of the accumulation of organic materials. While there are no specific standards for farm water supplies in Australia, levels of BOD and P measured in the waste-water exceed the Chinese standards for agricultural water (Anon. 1988). This is indicative that the used wash-water is unsuitable for discharge into waterways. Added to this, the presence of plant pathogens suggests a possible biological hazard if the water were reused without treatment for crop irrigation or carrot washing. Where various types of vegetables are washed in the same system, water treatment or replacement will be needed to prevent cross-contamination between heavily contaminated vegetables (which are usually cooked) and cleaner salad vegetables (which are usually eaten raw). Wash water contaminated with human pathogens has been shown to infiltrate fresh-cut lettuce and tomatoes through the stomata and wound sites (Zhuang et al. 1995; Seo and Frank 1999).

In Australia, there are numerous sanitising agents used throughout the horticultural industry, not only chlorine. Ongoing research is needed to optimise vegetable washing systems using different sanitisers, produce types, pathogens, surfaces, temperature, pH, water hardness, organic matter load, surfactants, flocculants, and filters. Further research is also needed on by-products from the breakdown of sanitisers (which may be toxic) and disposal methods for used wash-water. This would improve the performance of washing systems and potentially decrease waste production, water consumption, energy consumption, pathogen dispersal, environmental contamination, and residual health risks.

Acknowledgments

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References

- Anon. 1988. National standards of the People's Republic of China, environmental quality standards for surface water UDC614.7, GB3838-88 <<http://svr1-pek.unep.net/soechina/water/standard.htm>>.
- AOAC (Association of Official Analytical Chemists) 1984. Official methods of analysis, 14th ed. USA, Association of Official Analytical Chemists.
- Behrsing, J., Winkler, S., Franz, P., and Premier, R. 2000. Efficacy of chlorine for inactivation of *Escherichia coli*. *Postharvest Biology and Technology*, 19, 187–192.
- Bessems, E. 1998. The effect of practical conditions on the efficacy of disinfectants. *International Biodeterioration and Biodegradation*, 41, 177–183.
- Beuchat, L.R. and Ryu, J-H. 1997. Process handling and processing practices. *Emerging Infectious Diseases*, 3, 459–465.
- Coates, L. and Johnson, G. 1996. Postharvest diseases of fruits and vegetables. In: Brown, J.F. and Ogle, H.J., ed., *Plant pathogens and plant diseases*. Australia, Rockvale Publications.
- Dychdala, G.R. 1977. Chlorine and chlorine compounds. In: Block, S., ed., *Disinfection, sterilization and preservation*. London, Lea and Febier, 167–195.
- Gibson, H., Elton, R., Peters, W., and Holah, J.T. 1995. Surface and suspension testing: conflict or complementary. *International Biodeterioration and Biodegradation*, 36, 375–384.
- Graham, B.M. 1978. The development of Australian legislation for disinfectants. *Australian Journal of Hospital Pharmacology*, 8, 149–155.
- Hamilton, A. and Mebalds, M. 2000. In: *In the wash* newsletter, volume 1. Melbourne, Department of Natural Resources and Environment.
- Kostenbauder, H.B. 1977. Physical factors influencing the activity of antimicrobial agents. In: Block, S., ed., *Disinfection, sterilization and preservation*. London, Lea and Febier, 912–932.
- Little, C.L., Monsey, H.A., Nichols, G.L., and de Louvois, J. 1997. The microbiological quality of refrigerated salads and crudites. *PHLS Microbiology Digest*, 14, 142–146.
- Morgan, B. 2001. Exposing *Erwinia* newsletter, Issue 3 (March 2001). Adelaide, South Australian Research and Development Institute.
- Sabaa-Srur, A.U.O., Brecht, J.K., Sargeant, S.A., and Bartz, J.A. 1993. Recommended chlorine levels for treatment of float-tank water in tomato packinghouses. *Acta Horticulturae*, 343, 337–343.
- Segall, R.H. 1968. Fungicidal effectiveness of chlorine as influenced by concentration, temperature, pH and spore exposure time. *Plant Pathology*, 58, 1412–1414.
- Seo, K.H. and Frank, J.F. 1999. Attachment of *Escherichia coli* 0157:H7 to lettuce leaf surface and bacterial viability in response to chlorine treatment as demonstrated by using confocal scanning laser microscopy. *Journal of Food Protection*, 62, 3–9.
- Tauxe, R., Hedberg, C., Potter, M., Madden, J., and Wachsmuch, K. 1997. Microbial hazards and emerging issues associated with produce. A preliminary report to the National Advisory Committee on microbiological criteria for foods. *Journal of Food Protection*, 60, 1400–1408.
- van Klingeren, B., Koller, W., Bloomfield, S.F., Bohm, R., Cremieux, A., Holah, J., Reeybrouck, G., and Rodger, H.J. 1998. Assessment of efficacy of disinfectants on surfaces. *International Biodeterioration and Biodegradation*, 41, 289–296.
- White, G. 1999. *Handbook of chlorination and alternative disinfectants*. USA, Van Nostrand Reinhold.
- Zhuang, R-Y, Beuchat, L.R., and Angulo, F.J. 1995. Fate of *Salmonella montevideo* on and in raw tomatoes as affected by temperature and treatment with chlorine. *Applied Environmental Microbiology*, 61, 2127–2131.

Storage of Oriental Bunching Onions

Wu Li*

Abstract

Weight loss, visual quality, leaf discoloration and growing point extension are the major storage quality parameters for oriental bunching onion. With oriental bunching onions stored in the open air (30 to 40% relative humidity, RH) during winter, weight loss can be very high, sometimes greater than 50%.

Temperature and relative humidity were the two most important limiting environmental factors affecting the storage life of oriental bunching onions. Weight loss, leaf discoloration and growing point extension were monitored over a range of storage temperatures and humidities. Deterioration was more serious at 5 and 15°C than at 0°C. Temperatures of -1.5°C and -2°C were satisfactory for long-term storage, with leaves maintaining a good appearance for a further 7 days after withdrawal to 2°C. Appearance was better after storage at 95–100% RH than at 70–80% or 40–50% RH. A combination of low temperature and high relative humidity is ideal for storage of oriental bunching onions. Control of temperature with refrigeration is preferred, if economically feasible. Similarly, maintaining humidity to reduce moisture loss will improve quality. Simple methods for this range from use of film wraps to plastic sheets placed over shoots in bulk storage.

Atmosphere modification (2–3% O₂/1–2% CO₂, and 5–6% O₂/1–2% CO₂) was found to be more effective than air storage in extending the shelf life of oriental bunching onions. Growing point extension was also slowed by modified atmosphere storage.

ORIENTAL bunching onions are one of the main vegetables in northern China, with 8.5 million tonnes produced every year. They are stored in the open air during the winter, during which time weight loss is very high. This study was conducted to investigate the effects of temperature, relative humidity and atmosphere modification on the visual quality of oriental bunching onions.

Materials and Methods

Freshly harvested 'Zhangqiu' oriental bunching onions grown in Sanhe County of Hebei Province were used in all experiments. ('Zhangqiu' is the main variety currently grown in this production area.) Ideal oriental bunching onions were selected and randomly

placed in boxes and controlled atmosphere bags at 15, 5, 0, -1, -2, or -4°C. The following relative humidity (RH) and atmospheric conditions were trialed: 95–100%, 70–80%, and 40–50% RH; and air, 2–3% O₂/1–2% CO₂, and 5–6% O₂/1–2% CO₂. Samples were removed from storage after 0, 2, 4, 6, 8, 12, 16, 20, or 24 weeks. Three replicates were used per treatment.

A TC-8800 colour and colour difference meter was used for colour measurements. Visual quality was divided into 9 scores, where: 9 = fresh with green leaves; 5 = fresh with mostly green leaves; and 1 = wilting with yellow leaves.

Results and Discussion

Effects of temperature and relative humidity on shelf life

Temperature and relative humidity were the two most important limiting environmental factors affecting the

* Beijing Vegetable Research Center, PO Box 2443, Beijing, People's Republic of China.

storage life of oriental bunching onions. Weight loss (Figure 1), leaf discoloration and growing point extension were monitored over a range of storage temperatures and humidities. Deterioration was more serious at 5 and 15°C than at 0°C. Temperatures of -1.5°C and -2°C were satisfactory for long-term storage, with leaves maintaining a good appearance for a further 7 days after withdrawal to 2°C. Appearance was better after storage at 95–100% RH than at 70–80% or 40–50% RH.

A combination of low temperature and high relative humidity is ideal for storage of oriental bunching onions. Control of temperature with refrigeration is preferred, if economically feasible. Similarly, maintaining humidity to reduce moisture loss will improve quality. Simple methods to do this range from the use of film wraps to plastic sheets placed over shoots in bulk storage.

Effect of atmosphere modification on shelf life

Atmosphere modification (2–3% O₂/1–2% CO₂ or 5–6% O₂/1–2% CO₂) was found to be more effective than air storage in extending the shelf life of oriental bunching onions. Growing point extension was also slowed by modified atmosphere storage (Figure 2).

Modified atmosphere packaging (MAP)

Package weight affected the atmospheric composition and visual quality of oriental bunching onions stored in MAP bags. Packages containing 1, 2, 4 or 5 kg of

onions reached steady state oxygen concentrations of approximately 14, 10, 6 and 3%, respectively, after a few days at 0°C (Figure 3A). Visual quality was best in packages with the lowest oxygen concentration (Figure 3B). The atmosphere within each package changed very little after it reached a steady state (Figure 3A).

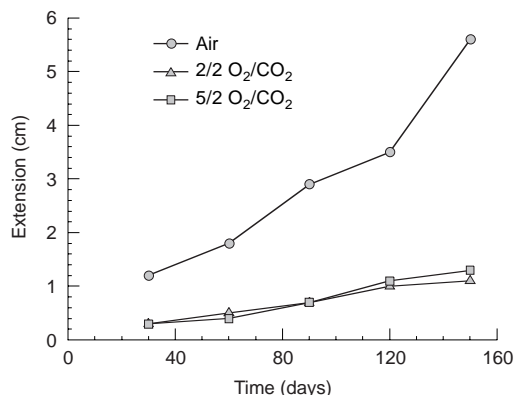


Figure 2. Reduction in growing point extension by modified atmosphere storage.

The practical introduction of MAP depends on cost and return. For MAP to generate stable atmospheres, refrigeration is needed, or at least an environment which guards against temperature abuse. MAP bags and refrigeration are currently used for garlic shoots, but these retail at four times the price of oriental bunching onions (and hence the additional cost can be justified).

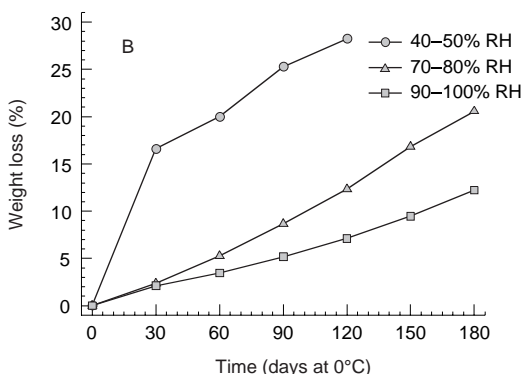
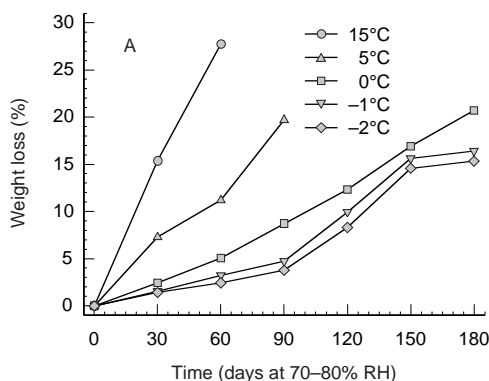


Figure 1. Weight loss of oriental bunching onions during storage at various temperatures (A) and relative humidities (B).

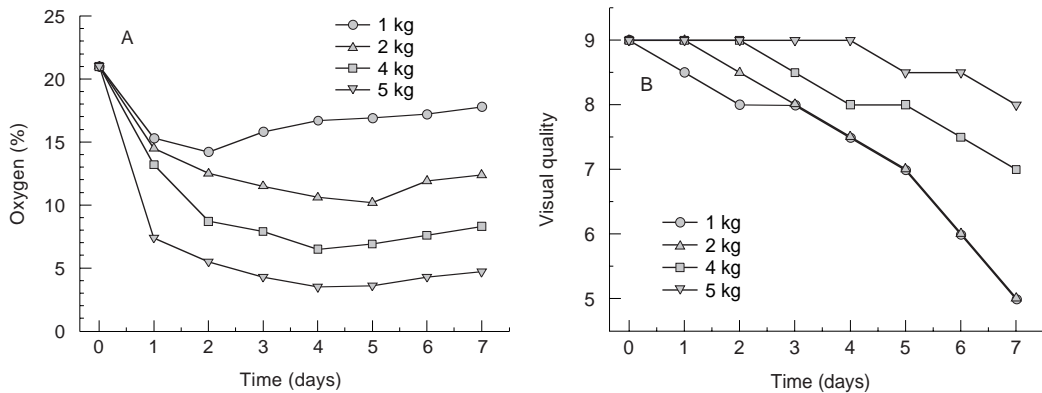


Figure 3. Package weight of oriental bunching onions stored in modified atmosphere packaging (MAP) bags affects both the (A) oxygen concentration, and (B) the visual quality (see text) over time.

Traditional storage methods of oriental bunching onions are widely used in northern China. Liu Yehe (1956) and Lu Renqing (1981) point out that these methods do not inhibit leaf discoloration and growing point extension. The results of our study are similar to those of Li Xihong and Chen Li (2000) who found that 0°C, 95–100% RH and 1% O₂/5% CO₂ are suitable storage conditions for young oriental bunching onions.

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References

- Liu Yehe 1956. Vegetable storage in Beijing suburbs. Publishing House of Economics, 72–85.
- Lu Renqing 1981. The handbook of vegetable production. Publishing House of Beijing, 346–379.
- Li Xihong and Chen Li 2000. Practical storage technology of fruits and vegetables. Scientific and Technical Documents Publishing House, 426–427.

Storage of Chinese Cabbage

Lipu Gao, Shufang Zheng, Wu Li, and Ping Wu*

Abstract

Chinese cabbage is a popular vegetable in China and is cultivated in most areas. The total production area is about 700,000 ha. Chinese cabbage is stored for provision to markets during winter. Seed is planted in early autumn and the crop harvested at the beginning of winter (in Beijing, seed is planted in early August and harvesting takes place in early November). Much more attention is paid to the storage capacity when selecting cultivars and in growing Chinese cabbage for storage. Chinese cabbage makes up almost half the autumn vegetable production in northern China.

THE methods of storing Chinese cabbage have evolved over a long period. In some years up to 30 Mt may be stored. The storage methods include stacked storage, covered storage, and pit storage. In the 1970s, cold rooms were built, and Chinese cabbage was stored in them; in the 1980s, the Beijing Vegetable Research Center and Tsinghua University cooperated to develop a forced-air ventilation system; in the 1990s the system was adopted in Beijing, Tianjin, and inner Mongolia for Chinese cabbage. In Beijing, traditional storage methods have almost passed out of use.

Stacked Storage

This form of storage is used in mild climatic areas or for short-term storage after harvest. In the field or a shaded place, the heads are stacked head inward and tail outward in either parallel-sided or cone-shaped stacks. Enough space is left between the heads to allow air circulation. Depending upon the surrounding temperature, the top of the stack may be covered when it is very hot or cold, otherwise cold air passing through the stack carries heat away.

Covered Storage

This is also called ditch storage. In the Beijing area, the depth is 5–10 cm more than the length of Chinese

cabbage; the width is 1 m, with west–east orientation. The ditch length is determined by the amount to be stored. The key point for ditch storage is ground temperature: the closer it is to 0°C the better. Some assistance can be given to cooling the ditch such as a shading hedge or ventilation hole. So long as the surrounding temperature causes no damage to Chinese cabbage, they are left in the field. In the ditch, the heads of Chinese cabbage are packed closely together and the top is covered with leaves. When the surrounding temperature falls, the top is covered with soil. The temperature of the heads of cabbage must be held at 0°C. While exploiting low temperature and buffering effects of soil to get long storage life, there are disadvantages, such as difficulty of inspection and high losses.

Pit Storage

This is the most common form of storage used for Chinese cabbage. Pits may be temporary—built with soil and wood, or permanent—built with bricks, cement, wood, or steel. All kinds permit good ventilation and temperature insulation.

Depending on the climate and level of groundwater, three kinds of pit can be built: above ground, half ground, and ground. With pit storage, Chinese cabbage is stored from November to March in the following year. After harvest, the cabbages are first trimmed and then arranged in parallel wall-type stacks with one head distance between the stacks. Ventilation is achieved by opening or shutting ventilation

* Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, People's Republic of China.
Email: <zhengshf@btmail.net.cn>

windows and shifting the heads of Chinese cabbage. Losses during pit storage are about 30–35%. Another disadvantage of pit storage is the labour cost for head shifting, which may be done up to 10 times during storage.

Cold Storage

Chinese cabbage is cold stored on steel shelves, or in baskets or cartons. Attention needs to be paid to the high cost and water losses.

Ventilated Storage

In order to reduce the need to turn the heads from time to time, semi-mechanical ventilated storage was developed by attaching ventilation systems to existing pit storages.

The ventilation system consists of an electric fan, ventilation channel, outlets for the channel, air mixing space, space between the Chinese cabbages, and

outlets from the pit. The fan pushes air into the ventilation channel and then through the outlets of the channel into the air mixing space, which is underneath the stacks of Chinese cabbage. Finally, the air is pushed through the spaces between the heads and then out through outlets from the pit.

In order to equilibrate the pressure in the ventilation channel, it was designed as a stair channel covered with cement slats. Spaces left between the slats form the outlets from the channel. The stacking format is ‘#’-like which guarantees that there will be spaces between the heads.

In ventilated storage, head shifting becomes unnecessary. It is no longer necessary to remove heads and reduce humidity and the natural source of cold air is well exploited. By using ventilated storage, 500 working days were saved and losses were reduced more than 10% when 100,000 kg Chinese cabbage was stored. The technique has been guaranteed a patent and granted an award by the Beijing Science Committee.

Fresh-cut Asian Vegetables — Pak Choi as a Model Leafy Vegetable

T.J. O'Hare*, A.J. Able†, L.S. Wong*, A. Prasad*, and R. McLauchlan*

Abstract

Pre-prepared fresh-cut salads are becoming increasingly common in the marketplace. Once dominated by lettuce, new vegetables are now being added to increase both flavour and visual appeal. A wide range of Asian brassicas is being sourced as constituents, but short shelf life because of yellowing is a problem to be contended with, and pak choi is a good example of this.

Yellowing in pak choi leaves is associated with a depletion of sugars (the main energy substrate). Increasing the initial leaf sugar level, or slowing the rate of sugar depletion, will directly increase shelf life. Sugars tend to be highest in younger leaves growing close to the tip, and lowest in leaves towards the base of the stem, even though the leaves may look similar in size and appearance. Removal of older leaves will therefore increase the life of a salad. Harvesting later in the day can also increase sugar levels, a result of photosynthesis during the day. Once harvested, leaves require sanitary washing and drying before packaging to avoid postharvest rots. Plastic packaging is vital to prevent wilting of leaves, but may also be used to provide an atmosphere conducive to slowing the rate of sugar depletion. Low oxygen (0.5–2% O₂) and enhanced carbon dioxide (2–10% CO₂) have been found to almost double shelf life in pak choi. However, for modified-atmosphere packaging to maintain an ideal atmosphere, stable temperature management is required, as high temperatures may lead to anaerobiosis and carbon dioxide toxicity of leaves. Common temperatures used for handling packaged salads range from 4° to 12°C. The above findings are for pak choi, but appear to apply also to many other Asian leafy brassicas used in fresh-cut salads.

ASIAN vegetables are a largely untapped resource for use in fresh-cut salads. Pre-prepared salads, both loose and pre-packed, are becoming increasingly common worldwide, catering to the consumer demand for convenience. A wide selection of Asian leafy vegetables can be utilised to add both visual appeal and flavour to salads. Many of these are members of the *Brassica* genus, which tend to have a common problem of leaf yellowing during postharvest handling.

The research literature on the practical use of Asian leafy brassicas is sparse, with much of the work having to be conducted from basic principles. In light of this,

our laboratory has conducted extensive trials investigating the use of Asian brassicas in fresh-cut salads (Prasad et al. 1997; Wong et al. 1997; O'Hare et al. 1998, 1999, 2000a,b; Able, Wong et al. 1999, 2000; Able, O'Hare et al. 2000). Because of the wide range of vegetables that can be used as salad constituents, our studies have focused on pak choi (*Brassica rapa* var. *chinensis*) as a model for other Asian leafy vegetables.

Effect of Physiological Leaf Age

Brassica plants grow in a rosette, with older leaves toward the periphery and younger leaves towards the central growing point. Harvest of leaves for fresh-cut salads normally involves the cutting of leaves from the base of the plant, without actually removing the plant from the ground. This can be done either manually or by machine, but in both cases the harvest will consist of leaves of different physiological ages.

* Horticulture Postharvest, Queensland Department of Primary Industries, Gatton Research Station, LMB 7, MS 437, Gatton, Queensland 4343, Australia. Email: <OhareT@dpi.qld.gov.au>.

† Department of Plant Science, The University of Adelaide, Waite Campus, Glen Osmond, South Australia 5064, Australia.

In pak choi (and in many Asian brassicas) it is not uncommon for older and younger leaves to be similar in appearance, colour, and perhaps even size. Initially, this is of no consequence in a salad mix, but in time the older leaves start to yellow and become more susceptible to bacterial rots. This appears to be a result of the lower initial sugar levels in older leaves. Yellowing is linked to the availability of energy substrates, and since older leaves at harvest tend to have a lower initial supply of sugars, they have a shorter shelf life, yellowing significantly earlier (Figure 1). Consequently, avoiding the inclusion of older leaves in a salad mix increases salad shelf life. While there are several possible approaches to achieving this, it is an area in which more research is needed.

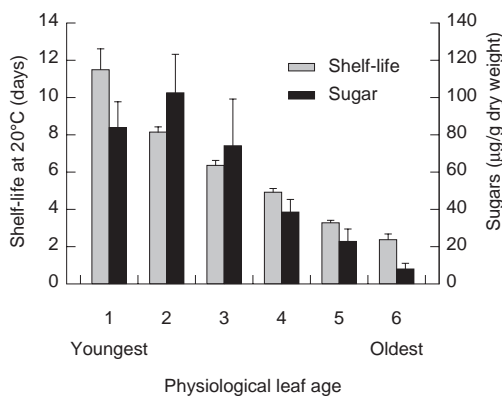


Figure 1. Shelf-life and initial sugar level of pak choi leaves of differing physiological age.

Moisture Loss of Leaves

One of the most obvious problems with pak choi leaves is their propensity to wilt. This becomes exceedingly obvious when leafy salads are dispensed into supermarket display cabinets without the benefit of plastic packaging. Most, if not all, Asian leafy vegetables react no differently from lettuce and other Western leafy salad constituents, and will lose moisture quickly.

Packaged salads tend to retail at higher prices, which may reflect the added cost in manufacture, but they do reduce moisture loss very effectively, and are considerably more efficient than manually misting loose leaves, or treating leaves with an anti-transpirant (Figure 2).

One issue that should be emphasised is that plastic packaging does maintain a very high relative humidity, and hence sanitary washing before packing is essential to avoid bacterial rots. Again, pak choi is no different to conventional pre-prepared salad vegetables in this regard.

Modified Atmosphere Packaging

An additional advantage of plastic packaging is the ability to modify the package atmosphere to extend the life of the salad. With pak choi, yellowing can be retarded by reducing the oxygen concentration to approximately 0.5–2% and increasing carbon dioxide concentration to between 2 and 15% (Figure 3).

This reduces the rate at which sugars are used and can almost double the shelf life of leaves. Exposure to oxygen levels lower than 0.5% and carbon dioxide

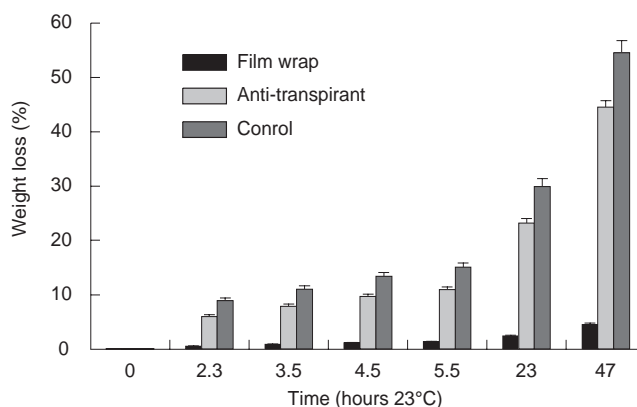


Figure 2. Retardation of moisture loss in pak choi leaves using plastic film and anti-transpirants. Of the two alternatives, film wraps were considerably more effective.

levels higher than 15% for an extended length of time should be avoided, as the former will result in anaerobiosis and the latter will result in carbon dioxide toxicity, both of which will cause off-odours, and eventually tissue breakdown.

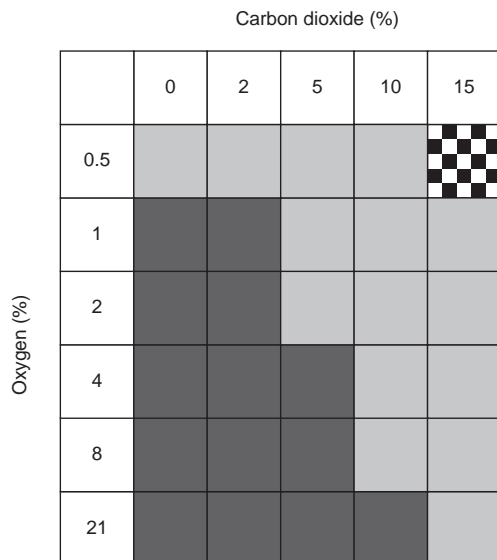


Figure 3. Combinations of oxygen and carbon dioxide capable of delaying leaf yellowing in pak choy (dark grey = no effect; light grey = increase; chequered = toxic to leaves)

Conventional modified atmosphere packaging requires strict temperature management of the handling system, as increases in temperature will lead to a change in the package atmosphere. The change can either shift the atmosphere away from the ideal (and shorten shelf life), or shift the atmosphere into oxygen and carbon dioxide concentrations that are toxic to the product. Packages are normally designed to operate within a narrow temperature range, and are usually marketed between 4°C and 12°C.

Conclusions

Asian leafy vegetables appear to be amenable to use as salad constituents. They should be treated similarly to other leafy vegetables in that they require sanitary washing and will lose moisture if not packaged adequately. Unlike lettuce, the shelf life of many Asian brassicas is limited by leaf yellowing rather than browning. However, atmospheres for retarding yellowing are similar for that used to extend lettuce shelf life, and hence mixing of vegetables should not be restricted.

Acknowledgments

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References

- Able, A.J., O'Hare, T.J., Wong, L.S. and Prasad, A. 2000. Extending the shelf life of broccoli florets and pak choy leaves. In: Johnson, G.I., Le Van To, Nguyen Duy Doc, and Webb, M.C., ed., Quality assurance in agricultural produce. Proceedings of the 19th ASEAN/1st APEC Seminar on Postharvest Technology, 9–12 November 1999, Ho Chi Minh City, Vietnam. Canberra, ACIAR Proceedings No. 100, 444–450.
- Able, A.J., Wong, L.S., Prasad, A., and O'Hare, T.J. 1999. Postharvest physiology of pak choy (*Brassica rapa* var. *chinensis*). Australasian Postharvest Horticulture Conference Proceedings, 3–8 October 1999, Waitangi, New Zealand, 33.
- Able, A.J., Wong, L.S., Prasad, A., and O'Hare, T.J. 2000. Physiological leaf age and senescence of pak choy leaves. 'Combio 2000', 11–14 December 2000, Auckland, New Zealand.
- O'Hare, T.J., Able, A.J., Wong, L.S., and Prasad, A. 1999. Retardation of yellowing in broccoli florets and pak choy leaves by 1-methylcyclopropene. Australasian Postharvest Horticulture Conference Proceedings, 3–8 October 1999, Waitangi, New Zealand, 34.
- O'Hare, T.J., Wong, L.S., and Prasad, A. 1998. Extension of postharvest shelflife of fresh-cut pak choy, tatsoi, mizuna and choy sum by atmosphere optimisation. 4th Australian Horticulture Conference, 14–17 October, Melbourne, 36.
- O'Hare, T.J., Wong, L.S., Prasad, A., and Able, A.J. 2000a. Impact of exogenous and endogenous factors in the shelflife of fresh-cut leafy Asian vegetables. 4th International Conference on Postharvest Science, 26–31 March 2000, Jerusalem, Israel (in press).
- (2000b). Atmosphere modification extends the postharvest shelflife of fresh-cut leafy Asian brassicas. Proceedings of the 3rd ISHS International Symposium on Brassicas, 5–9th September 2000, Wellesbourne UK. Acta Horticulturae, 539, 103–107.
- Prasad, A., Wong, L.S., and O'Hare, T.J. 1997. Temperature storage of minimally processed Asian leafy vegetables. Australasian Postharvest Conference, 1997, Hawkesbury, New South Wales, 322–325.
- Wong, L.S., Prasad, A., and O'Hare, T.J. 1997. Shelf-life extension of minimally-processed Asian vegetables using controlled atmospheres. Australasian Postharvest Conference, 1997, Hawkesbury, New South Wales, 211–214.

Forced-air Pre-cooling of Vegetables

Lipu Gao, Shufang Zheng, and Wu Li*

FORCED-air pre-cooling is a technique for rapidly removing the heat from vegetables. The cost of forced-air pre-cooling is almost same as that for cold room pre-cooling, but forced-air pre-cooling is faster.

In China, research on, and application of, forced-air pre-cooling began only recently. Since the 1980s the production and transportation of vegetables has increased sharply, and almost all pre-cooling has been cold room pre-cooling. The forced-air pre-cooling system was introduced from Japan and research on the technique undertaken in Beijing Vegetable Research Center. Since the 1990s, exports of vegetables have been increasing annually, and the cold room pre-cooling capacity is no longer sufficient. Beijing Vegetable Research Center and Tsinghua University cooperated to design and develop a forced-air pre-cooling system, in order to meet market demand and increase pre-cooling efficiency.

Three models of portable equipment for forced-air pre-cooling have been developed and cold-room

tested during three years of research: CYYLJ-16 (0.5–1 t capacity); CYYLJ-32(1–2 t); and CYYLJ-80 (3–4 t). Also, a pre-cooling cold room with 12 t capacity was constructed at a vegetable production demonstration in Chaoyang District.

After an evaluation of the system, it is considered to be efficient in pre-cooling vegetables. The internal temperature of Chinese cabbage was still 6–8°C after 20 hours in a cold room, but it had fallen to 4°C after 5 hours of forced-air pre-cooling. Using forced-air pre-cooling, the temperature of tomatoes could be reduced from 27° to 10°C in 5 hours; of sweet pepper from 34° to 13°C in 3.5 hours; and of cucumber from 28° to 13°C in 3.5 hours.

In order to promote application of the equipment, operational guides to pre-cooling ten kinds of vegetables (tomato, cucumber, sweet pepper, eggplant, snow pea, broccoli, Chinese cabbage, lettuce, celery, and pak choy) were developed. The forced-air pre-cooling technique is now in use in the Beijing area.

* Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, China. Email: <zhengshf@btamail.net.cn>.

Effect of Hot Water Treatment on Postharvest Shelf Life and Quality of Broccoli

Ping Wu and Wu Li*

Abstract

Broccoli was stored at 0, 10, or 20°C after immersion in hot water (38–52°C) for 10 or 30 minutes. Yellowing of broccoli was significantly slowed and shelf life significantly increased when broccoli was treated at 42–46°C and then stored at 10 or 20°C. Heat injury occurred when treatment was higher than 46°C. Broccoli shelf life was 2–3 days longer when stored at 10°C and 1–2 days longer when stored at 20°C after hot water treatment at 46°C. There was no significant effect of treatment on shelf life after long-term storage at 0°C. Weight loss was reduced by hot water treatment and the respiratory behaviour of the broccoli also changed.

BROCCOLI is a highly perishable fresh vegetable. After harvesting, it turns yellow and becomes unmarketable within 1–3 days at room temperature (Wang and Hruschka 1977). Storage at low temperature can reduce the rate of senescence. Storage in a controlled atmosphere (CA) or modified atmosphere (MA) can also extend the storage life of broccoli (Barth et al. 1993). Zong et al. (1985) reported that the shelf life of broccoli was more than 4 weeks when held at 0°C using MA packaging.

Heat treatments can also alter senescence of broccoli (Paull 1990). Forney (1995) and Kazami et al. (1991a, 1991b) reported that dipping broccoli in hot water delayed yellowing. Kazami et al. (1991a,b) reported the effect of hot treatments on loss of soluble protein, respiration, and ethylene production.

In the experiments detailed in this paper, the optimal hot water treatment to maximise storage life of broccoli cultivars common to China was identified. The effects of treatments on weight loss and decay were also investigated.

Materials and Methods

Hot water treatment

Three cultivars of broccoli were used in the experiments: 'Lilu', 'Luling', and 'B-53'.

The broccoli was immersed in hot water at selected temperatures between 38 and 52°C for 10 or 30 minutes and then dried by shaking gently and leaving at room temperature for 30 minutes. The treated broccoli was then stored at the desired temperature (0, 10, or 20°C).

Packaging

The broccoli for grading and colour assay was placed into 0.03 µm polyethylene bags with folded openings. The broccoli used for respiration measurements was put into a container with a known volume when required.

Colour assay

The colour was determined using a chromameter (CR-200). Five broccoli heads from each treatment were assayed. A position approximately 3 cm from the flower centre was selected as the assay site. Three sites were assayed for each broccoli head.

* Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, China. Email: <liwu@public.bta.net.cn>.

Respiration assay

The storage container was sealed before assay. The CO₂ concentration was determined by near infrared (NIR) analysis (RLR-2000) after several hours.

Results

Quality changes and general observations

The most significant effect on the quality of broccoli following treatment with hot water in the range 38–50°C was the retardation of yellowing. If treated with hot water higher than 48°C, heat injury occurred and off-odours were produced such that its edibility was lost. The ideal hot water treatment was 46°C for 10 minutes. After storage at 10 or 20°C for several days, the quality of the hot water dipped broccoli changed less than that of untreated samples. No obvious heat injury on the surface of the broccoli head was found.

Postharvest colour change

The most significant effect of hot water treatment on broccoli is the retardation of yellowing, even in those broccoli heads treated with higher temperature water such that heat injury occurred. In the range 42–48°C, the higher the hot water temperature was, the higher the hue angle of the broccoli after storage at 10°C (Figure 1) or 20°C (Figure 2).

Respiration rates of broccoli after harvest

The respiration rate of broccoli after harvest was determined for a combination of different hot water treatments and storage temperatures (Figures 3–5). The respiration rate of broccoli was significantly altered by the hot water treatments. At 10°C, the broccoli treated at 42, 44, and 46°C all reached the highest respiration rate on the sixth day after harvest (Figure 4). However, the control reached its respiration peak on the fourth day after harvest. Changes in the respiration rate of broccoli stored at 0 and 20°C were difficult to determine.

Weight loss of broccoli during storage

The weight loss during storage of broccoli treated with hot water was significantly less than that of untreated samples (Table 1).

Shelf life of broccoli

As the yellowing of broccoli was delayed by hot water treatment, the shelf life of broccoli was therefore

extended (Figure 6). After hot water treatment, the shelf life of broccoli was extended by 2–3 days when stored at 10°C and 1–2 days when stored at 20°C. The visual quality, smell, and flavour of treated broccoli did not show the deterioration that untreated broccoli did after storage at 10° or 20°C. There was no obvious effect of hot water treatment on storage life when the broccoli was stored at 0°C for 6 weeks.

Table 1. The weight loss (%) of broccoli after 14 days storage at 10°C.

Treatment temperature (°C)	Treatment time (minutes)	
	10	30
38	5.3	6.1
42	4.3	4.6
46	4.2	4.3
50	10.3	19.8
Control	5.7	

Discussion

From the results of our three experiments, treatment with hot water in the temperature range 38–48°C had the most obvious effect on slowing the otherwise rapid postharvest yellowing of broccoli. Generally, the effect was best when the broccoli was treated at 46°C for 10 minutes. Hot water treatment can also delay the yellowing of broccoli if the water temperature is lower than 46°C. Hot water treatment appeared to have a greater effect when maintained for a longer time; that is, in general the 30-minute treatment was more effective than the 10-minute treatment. At higher temperatures, heat injury was observed and was detrimental to broccoli storage.

Cultivar 'B-53' was able to endure the 48°C treatment for 10 minutes in our experiments. The treated broccoli had no obvious heat injury or off-odours after storage, and the yellowing was delayed significantly. Higher treatment temperature tolerance varied between cultivars. The optimal treatment temperature was also dependent upon the time of harvest. The ideal treatment therefore has to be determined for each season and each cultivar.

The growth conditions of broccoli can also influence the effect of postharvest heat treatment. In one of our experiments, many fungi infected the treated broccoli but there was no relationship between the extent of infection and the temperature of the hot water treatment. The control, on the other hand, suffered less

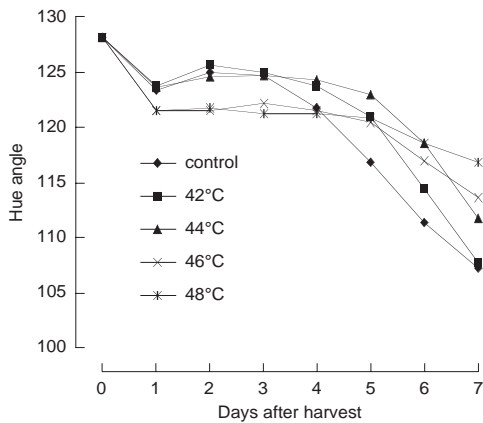


Figure 1. Postharvest colour changes in broccoli stored at 10°C following treatment with hot water at various temperatures.

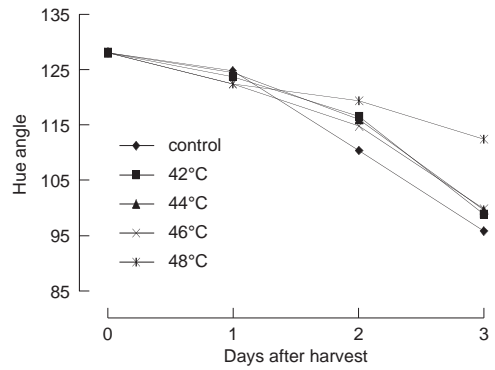


Figure 2. Postharvest colour changes in broccoli stored at 20°C following treatment with hot water at various temperatures.

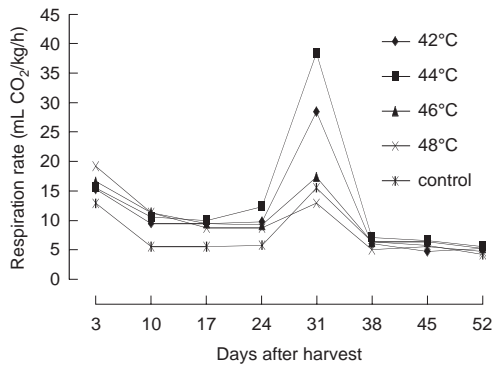


Figure 3. Postharvest respiration rate of broccoli stored at 0°C following treatment with hot water at various temperatures.

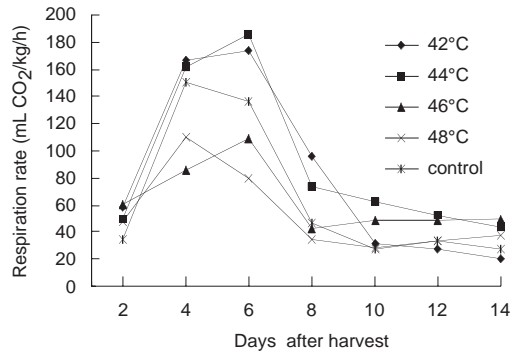


Figure 4. Postharvest respiration rate of broccoli stored at 10°C following treatment with hot water at various temperatures.

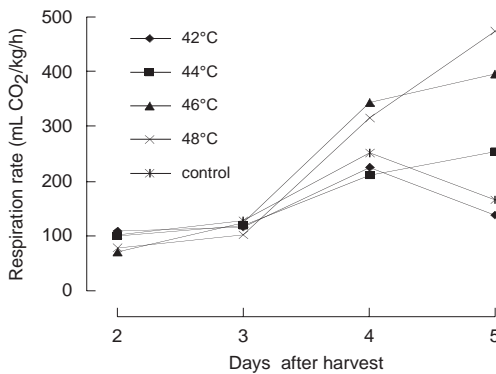


Figure 5. Postharvest respiration rate of broccoli stored at 20°C following treatment with hot water at various temperatures.

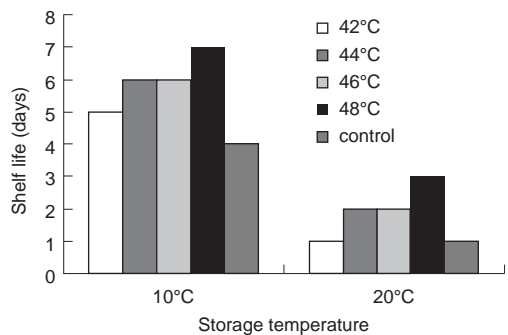


Figure 6. Effect of treatment with hot water at various temperatures on shelf life of broccoli stored at 10 and 20°C.

infection. Hot water treatment in this circumstance was not beneficial.

Three storage temperatures were selected in our experiments (0, 10, or 20°C). The results showed that hot water treatment can efficiently delay the yellowing and prolong the shelf life of broccoli when it is stored at 10 and 20°C. When the broccoli was stored at 0°C, heat treatment had no obvious effect. After 6 weeks of storage at 0°C, the untreated broccoli began to yellow, lose surface moisture, and show signs of fungal infection. The treated broccoli also started to lose moisture from the surface and become infected by fungi. Thus, we conclude that heat treatment before storage at 0°C will provide no benefits. Broccoli can be stored well at 0°C by using appropriate packaging and other methods.

Heat treatment changed the respiratory behaviour of broccoli so that the respiration peak of treated broccoli was delayed. However, owing to difficulties with our method for measuring respiration rates, we could not determine the exact respiration rate of the heat-treated broccoli. In the experiments, 3 to 4 broccoli heads were placed in one container to assay. Differences between the individual broccoli heads in respiratory rate and differing fungal infections on each head will influence not only the precision with which the respiratory rate can be measured but also the postharvest physiological state of other broccoli in same container. Hence, the experimental error will increase. This will be corrected in future experiments.

Based on theory and the results of our experiments, this treatment has potential for application in China. At present, the time from harvesting to marketing of broccoli in China is usually at least 1 to 2 days. In developed countries, there is a complete cold-chain system to ensure the postharvest quality of broccoli. However, methods widely used in developed countries such as pre-cooling have not been applied broadly in China, so the selling quality of broccoli cannot be ensured. Because of the limited mass production of broccoli by

individual farmers, especially in spring, the farmers cannot afford to purchase large amounts of pre-cooling equipment and refrigerated transport. The problem of lower selling quality of broccoli could be solved to some extent if the shelf life is increased by 1 to 3 days by heat treatment.

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References

- Barth, M.M., Kerbel, E.L., Broussard, S., and S. J. Schmidt, S.J. 1993. Modified atmosphere packaging protects market quality in broccoli spears under ambient temperature storage. *Journal of Food Science*, 58, 1070–1072.
- Forney, C.F. 1995. Hot-water dips extend the shelf life of fresh broccoli. *HortScience*, 30, 1054–1057.
- Kazami, D., Sato, T., Nakagawa, H., and Ogura, N. 1991a. Effect of pre-storage hot water dipping of broccoli heads on shelf life and quality during storage. *Nippon Nogeikagaku Kaishi*, 65(1), 19–26. (in Japanese with English summary)
- 1991b. Effect of pre-storage hot water dipping of broccoli heads on soluble protein, free amino acid contents and protease activities during storage. *Nippon Nogeikagaku Kaishi*, 65(1), 27–33. (in Japanese with English summary)
- Paull, R.E. 1990. Postharvest heat treatments and fruit ripening. *Postharvest News & Information*, 1, 355–363.
- Wang, C.Y. and Hruschka, H.W. 1977. Quality maintenance in polyethylene-packaged broccoli. U.S. Department of Agriculture Marketing Report, 1085.
- Zong, R.J., Huang, B.Y., and Li, W. 1985. Studies on storage technique of broccoli. *Chinese Vegetables*, 15. (in Chinese)

Effect of Salicylic Acid on Shelf Life of Broccoli

Ping Wu and Wu Li*

Abstract

Salicylic acid (SA) solution was tested as an ethylene inhibitor in broccoli. Broccoli was immersed in 0 to 2 g/L SA solutions for 10 minutes, stored at 10°C and changes in colour, and in content of soluble protein and sugar were determined. It was found that low-concentration SA dips (0–0.5 g/L) delayed yellowing of broccoli, but immersion at high concentrations (2 g/L) had no benefit on increasing shelf life. However, the effect of SA in low concentration was not statistically significant.

SALICYLIC acid (SA) is a simple phenolic compound occurring extensively in higher plants. It plays a role in regulating many physiological and biochemical reactions in plants (Li and Pan 1995). Raskin (1992) proposed that SA could be regarded as a new kind of endogenous phytohormone. Because it inhibits the biosynthesis of ethylene, it has been used to extend the shelf lives of fruit and vegetables. Research results have shown that SA inhibits some postharvest physiological changes in apples and has some effectiveness in keeping the freshness of tomatoes, apples, and pears (Yan et al. 1998). Li and Han (1998) found that SA gave some control of postharvest rots in peaches.

Broccoli is a highly perishable vegetable. After harvesting, it turns to yellow and becomes unmarketable very quickly at room temperature (Wang and Hruschka 1977). Research has shown that ethylene is one of the main factors causing yellowing and senescence of postharvest broccoli (Wang 1977).

In the work reported here, a SA solution was tested as an ethylene inhibitor in broccoli. The effects of immersion in different concentrations of SA solution on colour changes, soluble protein content, and shelf life were investigated.

Methods and Materials

Hue angle (used as a measure of yellowing) was measured using a Minolta chromameter (CR-200). Three sites were assayed on each floret and the average of 10 readings on florets was calculated.

Soluble protein was extracted using a sodium dodecyl sulfate (SDS)-based method (Pogson and Morris 1997) and was then assayed using a protein analysis kit (Bio-rad) based on the Bradford method (Bradford 1976).

General appearance (GA) was determined using a scale of 1 to 9, where 9 was the best condition and 1 was the worst. When florets reached a GA score of 5.5, they were considered to be at the end of their shelf life.

Results and Discussion

Postharvest colour change

From the results of colour changes in broccoli (Figure 1), it was found that the yellowing rate of the broccoli treated with a SA solution whose concentration was in the range 0.01–0.5 g/L was lower than that of control samples. Treatment with SA solutions of higher concentration gave no benefit in slowing down the yellowing of broccoli.

Soluble protein content during storage

The results of soluble protein content determination (Table 1) showed that soluble protein content fell during storage at 20°C, but the rate of decrease varies. After 3 days storage at 20°C, the soluble protein

* Beijing Vegetable Research Center, PO Box 2443, Beijing 100089, China. Email: <liwu@public.bta.net.cn>.

content was higher in treated broccoli than that in the control.

The postharvest shelf life of broccoli

As the yellowing of broccoli was delayed by SA treatment, the shelf life was therefore extended (Figure 2). When treated with a 0.01–0.5 g/L SA solution treatment, the shelf life was extended by 1 day when the broccoli was stored at 10°C. Within this range of SA concentrations, there was no difference between the effect of different concentrations on shelf life. Immersion at a higher concentration of 2 g/L had no benefit in increasing shelf life.

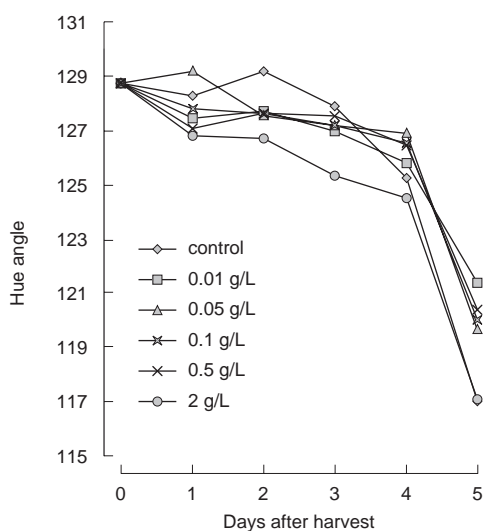


Figure 1. Postharvest colour change in broccoli following treatment with various concentrations of salicylic acid.

Table 1. Effect of salicylic acid (SA) treatment on soluble protein content of broccoli during storage at 20°C.

Days of storage	1	2	3
Control	11.16	5.79	5.56
0.1 g/L SA	12.09	7.90	7.30
0.5 g/L SA	10.83	8.71	8.78

Because there are no ethylene production data, the exact effect of SA on broccoli is not clear from this test. Compared with the effects of other ethylene

inhibitors on broccoli (Wang 1977), the effect of SA on broccoli shelf life is not significant.

Other researchers have found that low concentrations of SA similarly affect postharvest quality of other products: tomato (0.1 g/L; Yan et al. 1998), peach (0.1–0.3 g/L; Li and Han 1998), and pear (0.1 g/L; Yan et al. 1998). Our experiments reached a similar conclusion. However, further experimental work is needed to confirm the precise effect and mode of action of SA on shelf life of broccoli.

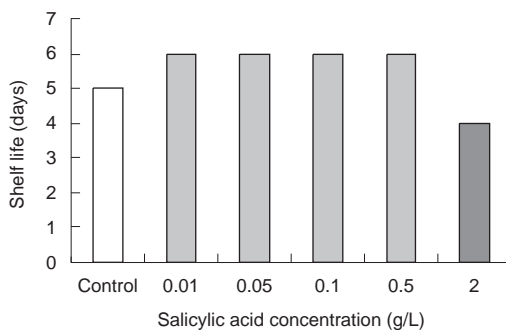


Figure 2. Effect of salicylic acid treatment on shelf life of broccoli stored at 10°C.

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References

- Bradford, M.M. 1976. Quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. *Analytical Biochemistry*, 72, 248–254.
- Li, D.H. and Pan, R.Z. 1995. Role of salicylic acid in plant. *Plant Physiology Communications*, 31(2), 144. (in Chinese)
- Li, L.P. and Han, T. 1998. Primary studies of salicylic acid on keeping freshness of peach. *Food Science*, 6, 61–63. (in Chinese)
- Pogson, B.J. and Morris, S.C. 1997. Consequences of cool storage of broccoli on physiological and biochemical changes and subsequent senescence at 20°C. *Journal of the American Society of Horticultural Science*, 122, 553–558.
- Raskin, I. 1992. Role of salicylic acid in plants. *Annual Review of Plant Physiology and Plant Molecular Biology*, 43, 439–463.

- Wang, C.Y. and Hruschka, H.W. 1977. Quality maintenance in polyethylene-packaged broccoli. US Department of Agriculture Marketing Report, 1085
- Wang, C.Y. 1977. Effect of aminoethoxy analog of rhizobitoxine and sodium benzoate on senescence of broccoli. *HortiScience*, 12, 54–56.
- Yan, T. et al. 1998. Effect of salicylic acid on fruit ripeness. *Acta Botanica Sinica*, 15(3), 61–64. (in Chinese)

Using Benzothiadiazole and Biocontrol Microorganisms for Protection of Melon from Diseases

Li Yazhen*, Li Cuiping*, Ma Huiru*, Wei Yongfei*, Wang Wei†, Zhang Liqun†, and Tang Wenhua†

Abstract

Melon production is seriously damaged by powdery mildew and postharvest diseases in inner-Mongolia, China. Benzothiadiazole (BTH) and some biological control microorganisms showed significant activity in suppressing these diseases. Seed treatment of Hualaishi melon using biocontrol agents T4, B908, and TK7a resulted in more healthy seedlings compared with non-treated controls. Postharvest application of biocontrol agents on melon fruits also significantly reduced production losses caused by rot diseases. CPF-10, B908, and T4 were the most effective strains in the postharvest test. BTH, a compound that can stimulate systemic acquired resistance (SAR) in various plants, was sprayed on the melon plants during the flowering period. This procedure reduced the incidence of powdery mildew disease. Furthermore, melon fruits after BTH treatment ripened one week earlier, and resulted in a higher economic return in the market. Our results from both greenhouse experiments and field trials suggested that application of BTH and biocontrol microorganisms is a practicable approach for melon production in China.

* Department of Crop Sciences, He Tao University, Linhe, China.

† Department of Plant Pathology, China Agricultural University, Beijing, 100094, China.

Participants

AUSTRALIA

- John Bagshaw**, Horticulture Postharvest, Queensland Department of Primary Industries, 80 Meiers Road, Indooroopilly, Queensland 4068.
Email: <Bagshaj@prose.dpi.qld.gov.au>.
- Grantley Chaplin**, c/- ACIAR Postharvest Technology Program, GPO Box 1571, Canberra ACT 2601.
- Ed Highley**, c/- ACIAR Postharvest Technology Program, GPO Box 1571, Canberra ACT 2601.
Email: <ed@arawang.com.au>.
- Robert Holmes**, Agriculture Victoria, Institute for Horticultural Development, Private Bag 15, Scoresby Business Centre, Victoria 3176.
Email: <Robert.Holmes@nre.vic.gov.au>.
- Greg Johnson**, ACIAR Postharvest Technology Program, GPO Box 1571, Canberra, ACT 2601.
Email: <johnson@aciarc.gov.au>.
- Andreas Klieber**, Department of Horticulture, Viticulture and Oenology, University of Adelaide, Waite Campus, PMB 1, Glen Osmond, SA 5064.
Email: <andreas.klieber@adelaide.edu.au>.
- Robyn McConchie**, Department of Crop Sciences, Faculty of Agriculture, University of Sydney, NSW 2006.
Email: <McConchieR@agric.usyd.edu.au>.
- Richard McLauchlan**, Queensland Horticulture Institute, Department of Primary Industries, 80 Meiers Road, Indooroopilly, Queensland 4068.
Email: <McLaucR@prose.dpi.qld.gov.au>.
- Stephen Morris**, Sydney Postharvest Laboratory, c/- Foodscience Australia, CSIRO, North Ryde, NSW 2113.
Email: <scmorris@postharvest.com.au>.
- Tim O'Hare**, Horticulture Postharvest, Queensland Department of Primary Industries, Gatton Research Station, LMB 7, MS 437, Gatton, Queensland 4343.
Email: <OhareT@dpi.qld.gov.au>.
- Bruce Tomkins**, Institute for Horticultural Development, 621 Burwood Highway, Knoxfield, Victoria 3180.
Email: <Bruce.Tomkins@nre.vic.gov.au>.
- Guang Wan**, Department of Crop Sciences, Faculty of Agriculture, University of Sydney, NSW 2006.
- Sherrie Wei**, School of Natural and Rural Systems Management, University of Queensland – Gatton.
Email: <s.wei@mailbox.uq.edu.au>.

Lung Wong, Horticulture Postharvest, Queensland Department of Primary Industries, Gatton Research Station, LMB 7, MS 437, Gatton, Queensland 4343.
Email: <wongl@dpi.qld.gov.au>.

CHINA

- Chen Fahe**, Xinjiang Melon Seed Section.
Email: <Fhchen298@chinaren.com>.
- Chen Nianlai**, Melon Institute, Gansu Agricultural University, Lanzhou 730070.
Email: <Melons@lz.gs.public.cn>.
- Chen Diankui**, Beijing Vegetable Research Center, PO Box 2443, Beijing 100089.
- Gao Lipu**, Beijing Vegetable Research Center, PO Box 2443, Beijing 100089.
- Hong Hu**, Academy of China Agriculture
- Huang Guangrong**, Hangzhou University of Commerce, 29 Jiao Gong Road, Hangzhou City, Zhejiang Province 310035.
- Li Wu**, Beijing Vegetable Research Center, PO Box 2443, Beijing 100089. Email: <Liwu@public.bta.net.cn>.
- Li Yazhen**, China Agriculture University, Beijing 100094.
- Ma Keqi**, Melon Institute, Gansu Agricultural University, Lanzhou 730070. Email: <Melons@lz.gs.public.cn>.
- Shen Lianqing**, Hangzhou University of Commerce, 29 Jiao Gong Road, Hangzhou City, Zhejiang Province 310035. Email: <lqshen@mail.hzic.edu.cn>.
- Shixiong Wong**, Beijing Science Committee
- Shuangqing Feng**, China Agriculture University, Beijing 100094.
- Shuang Zhang**, Academy of China Agriculture
- Sun Liang**, Hangzhou University of Commerce, 29 Jiao Gong Road, Hangzhou City, Zhejiang Province 310035.
- Tang Wenhua**, China Agriculture University, Beijing 100094. Email: <Tangwh@public.east.cn.net>.
- Wang Guanglin**, ACIAR China Office.
Email: <Guanglin.Wang@dfat.gov.au>.
- Wang Xiangyang**, Hangzhou University of Commerce, 29 Jiao Gong Road, Hangzhou City, Zhejiang Province 310035.
- Wei Yao**, Academy of China Agriculture
- Wu Ping**, Beijing Vegetable Research Center, PO Box 2443, Beijing 100089.

Wu Fangwen, Xinjiang Melon Seed Section.

Email: <Fhchen298@chinaren.com>.

Xixiang Li, Academy of China Agriculture

Xuejie Zhang, Academy of China Agriculture

Zhang Liqing, China Agriculture University, Beijing
100094.

Zhang Yanrong, Melon Institute, Gansu Agricultural
University, Lanzhou 730070.

Email: <Melons@lz.gs.public.cn>.

Zheng Shufang, Beijing Vegetable Research Center,
PO Box 2443, Beijing 100089.

<Email: Zhengshf@public.bta.net.cn>.

Zhibin Zhang, Academy of China Agriculture

FIJI

Rasea Osea, Ministry of Agriculture, Forests and Fisheries,

Extension Division, PO Box 24, Sigatoka.

Email: <rasea_o@yahoo.com>.

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA

An Chun Kab, Rung ra 888 Vegetable Research Institute of
D.P.R. Korea, Botong Gang District, Pyongyang.

Pak Yong Nam, Rung ra 888 Vegetable Research Institute
of D.P.R. Korea, Botong Gang District, Pyongyang.

MALAYSIA

Azmi Bin Aziz, Department of Agriculture, Agriculture

District Office, 29000 Temerlon, Panang DM, West

Malaysia

PAKISTAN

Ghulam Mustafa, Department of Agriculture, Livestock
and Fisheries, Agriculture Training Institute, Sakrand,
Sindh

Munawar Sultana Solangi, Department of Agriculture,

Livestock and Fisheries, Agriculture Training Institute,

Sakrand. Sindh. Email: <Solangi50@hotmail.com>.

PHILIPPINES

Robert Bakker, Agricultural Engineering Unit,

International Rice Research Institute, Los Baños, Laguna.

Mailing address: DAPO 7777, Metro Manila,

Philippines. Email: <r.bakker@cgiar.org>.

SRI LANKA

Perera Raiganage Hasitha Jayanihi, Ministry of

Women's Affairs, 177 Nawala Road, Colombo 5.

Wanninayake Banduwathi, Agriculture Department,

Anuradapura.

THAILAND

Sing Ching Tongdee, Postharvest Technology Department,

Thailand Institute of Scientific and Technological

Research, 196 Phaholyothin Road, Chatuchak, Bangkok

10900, Thailand. Email: <somsakc@mozart.inet.co.th>.

UZBEKISTAN

Abdikayumov Zaynilabiddin Abdivohidovich, Tashkent

State Agrarian University, Tashkent Region, Kibray

District 140. Email: <tsau@mail.tps.uz>.

VIETNAM

Vu Van Che, Food Crops Research Institute, Hai Duong.

Email: <RTCD@hn.vnn.vn>.