Postharvest Quality Changes in Dokong (*Lansium domesticum* Corr.) Harvested at Different Stages of Ripeness

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Abstract

Dokong harvested at different stages of colour development 4, 7, 10 and 14 days after the fruit yellowing stage were observed for quality changes after being stored for 5 days under ambient conditions. Fruit yellowing (FY) is the stage at which all dokong fruit in a bunch have a yellowish-green pericarp. Results from this experiment suggested that fruit of dokong could be harvested as early as at 4 days after FY (6–8 fruit in a bunch exhibited a shade of green on their skin, while the rest were yellow) if the fruit were to be stored for a longer period of time. The pericarp colour of fruit from all stages of ripeness changed to brownish-yellow after 5 days of storage. Fruit firmness decreased 2-fold after storage. The amount of total soluble solids (TSS) in fruit harvested at 4 and 7 days after FY was found to increase during storage whilst total titratable acidity (TTA) in fruit from all stages of ripeness decreased, which resulted in an increase in the TSS-to-TTA ratio. The fruit harvested at an early stage of ripeness were able to attain acceptable sweetness after 5 days of storage under ambient conditions.

DOKONG is another form of *Lansium domesticum* Corr. (Meliaceae) besides langsat (or lanzones of the Philippines), duku-langsat and duku. In terms of external and internal characteristics of the fruit from this species, dokong is intermediate between langsat and duku-langsat (Norlia 1997) while duku-langsat is intermediate between langsat and duku (Salma and Razali 1987). Dokong is generally regarded as superior to langsat and duku but its taste and flavour are comparable to duku-langsat. Dokong is almost seedless, thin-skinned and free of latex while langsat has 1–2 seeds and thin skin that exudates latex when peeled even when fully ripe (Bamroongrugsa 1992). Another good characteristic of dokong which is absent in duku-langsat is that all the fruit in a bunch ripen simultaneously which facilitates harvesting.

Dokong, which is known as 'longkong' in Thailand, is a new, important economic crop that is gaining popularity in Malaysia. The demand for this fruit is increasing tremendously compared to other *Lansium* species because the fruit is juicy and has a pleasant taste. However, reports on postharvest characteristics of dokong and other *Lansium* species in general are very limited. Some information on the compositional changes in langsat during growth and development are reported by Del Rosario et al. (1977) and Paull et al. (1987) and Ahmad Tarmizi et al. (1998) recently reported some changes in dokong fruit during maturation. According to Ahmad Tarmizi et al. (1998), the change in fruit colour was the best indicator for determining fruit maturation of

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Quality assurance in agricultural produce,
edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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(printed version published in 2000)

dokong since the degree of yellowness at different stages is quite easily distinguishable. Dokong fruit start to develop yellow colour on their pericarp about 87 days after fruit set (Norlia 1997) and the fruit can be harvested 11–17 days after that stage (Ahmad Tarmizi et al. 1998). At 11 days, all the fruit in a bunch have attained their maximum size and have developed a fully yellow colour and maximum soluble solids content, whilst at 17 days, fruit colour turns brownish-yellow. However, fruit harvested at this stage have a very short shelf life (about 4 days under ambient conditions). Harvesting the dokong fruit at earlier stages of colour development may help to extend the shelf life of fruit provided that the fruit quality is comparable to the fruit harvested at 11 days or at later stages. Therefore, this study aimed to determine the quality changes during storage at ambient temperature in dokong harvested at different stages of ripeness.

Materials and Methods

Dokong used in this study were obtained from the Malaysian Agricultural Research and Development Institute (MARDI) Research Station, Jeram Pasu Kelantan, in October 1998. The colour stage called 'fruit yellowing' (FY), at which all fruit in a bunch turned yellowish-green, was used as the basis for harvesting. Fruit bunches were harvested randomly from five trees at 4, 7, 10 and 14 days after FY (DAFY). Ten bunches from each colour stage were individually wrapped with newspaper, packed in corrugated fibreboard cartons and transported on the same day to the laboratory in Serdang, Selangor. Fruit were then stored for 5 days under ambient conditions (24–28°C, 70–80% relative humidity).

Observations on fruit quality such as colour, firmness, soluble solids content, acidity and dry matter content were carried out before and after the fruit were stored for 5 days. The surface colour of individual fruit was measured using a Minolta Chroma meter and the colour was recorded in numerical notation system as *L**, *a** and *b**, where: *L** indicates lightness or darkness (0, black; 100, white); *a** indicates the hue on a green-to-red axis (negative value, greeness; positive value, redness); and *b** indicates the hue on a blue-to-yellow axis (negative value, blueness; positive value, yellowness). The numerical values of *a** and *b** were converted into hue angle ($H° = \tan^{-1} b^*/a^*$) and chroma [$C^* = (a^{*2} + b^{*2})^{1/2}$] (Carreño et al. 1995; Nunes et al. 1995). *H*° is an angle in the colour wheel of 360°, with 0, 90, 180 and 270° representing the hue red–purple, yellow, bluish-green and blue, respectively, while *C** is the intensity of the hue (vivid or dull).

Fruit firmness was measured with a texture meter Steven's Texture Referencing & Analysis System using a 7 mm diameter Magness Taylor's plunger. The plunger was forced down the fruit surface to the distance of 5 mm from the original position without breaking the pericarp. For chemical analysis, the fruit aril was homogenised in a Waring blender and the homogenate was used to measure total soluble solids, total titratable acidity and dry matter content. Total soluble solids was determined with a hand-held digital refractometer (Model PR-1, Atago Co. Ltd., Tokyo Japan). Results were expressed as degrees Brix. Total titratable acidity was determined by titrating the known volume of homogenate with 0.1 N NaOH to the end point of pH 8.1 and results were expressed as percentage anhydrous citric acid. Dry matter was determined by drying the sample in an oven at 60°C for 36 h and its value was calculated based on percentage of water loss.

Results and Discussion

The pericarp colour of dokong changed from green to 'trace of yellow' as the fruit were approaching the ripening stage. In this study, the colour stage called 'fruit yellowing' (FY) was used as the basis for harvesting. The colour of each fruit in a bunch harvested at the FY stage varied from yellowish-green to greenish-yellow. The fruit took about 87 days after fruit set to reach this colour stage (Norlia 1997). As the fruit reached advanced stages of ripening, the green colour disappeared and the fruit became yellow. However, there were 6–8 fruit in a bunch harvested at 4 DAFY, and 1–2 fruit in a bunch (located at the bottom of the bunch) harvested at 7 DAFY, which still showed shade of green at the stylar end of the fruit. The colour of fruit harvested at different ripeness stages is presented in Table 1.

Data on fruit colour at harvest and after storage recorded using the *L**, *a* and b** notation system are presented in Table 2. Higher *L**, *a**, *b** and *C** values respectively indicated lighter, more reddish, more yellowish and brighter (more intense) surface colour of the fruit. Furthermore, fruit with higher *H*° or lower *H*° were more yellowish or more brownish, respectively. Generally, the colour of dokong at harvest was found to differ significantly with different ripeness stage as indicated by differences in *a**, *b** and *H*° values.

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Table 1. The pericarp colour of dokong fruit harvested at different stages of ripeness.

Days after fruit yellowing	Pericarp colour
4	Pale yellow with 6–8 fruit per bunch having a greenish colour at the stylar end
7	Deep yellow with 1–2 fruit located at the bottom of the bunch exhibiting a shade of green at the stylar end
10	Light to bright yellow
14	Brownish-yellow

Fruit harvested at 4 and 7 DAFY were yellow with a tinge of green as indicated by lower *a** and higher *b** values, whereas fruit harvested at 14 DAFY were brownish-yellow (higher *a**, lower *b** and lower *H°).* Results showed that the colour of fruit from all stages of ripeness changed to brownish-yellow after 5 days of storage under ambient conditions as indicated by the decrease in *H°* and *b** values and increase in *a** values. However, all stored fruit, regardless of ripeness stage at harvest, exhibited a similar brownish-yellow colour and there were no significant different in *L*, a*, b*, C** and *H°* values with stages of ripeness at harvest. Furthermore, the decrease in *L* v*alues and increase in *C** values in stored fruit showed that the stored fruit were darker and dull compared to the fruit before storage. These results indicated that dokong harvested at as early as 4 DAFY with 6–8 fruit in a bunch exhibiting a tinge of green were able to turn full yellow after storage. The fruit were considered mature and ready to be harvested at this stage. In lanzones (langsat), an another form of *Lansium,* a bunch was considered mature if all the fruit were dull-yellow without any tinge of green (Pantastico et al. 1975).

Fruit softening occurred in dokong during storage. Table 3 shows that fruit firmness was reduced by 50% after 5 days of storage under ambient conditions, regardless of the ripeness stage at harvest. However, there were no significant differences in fruit firmness between fruit of different ripeness stages both after harvest and after storage. The fruit could easily yield to pressure when pressed with fingers.

Dry matter (DM) content in dokong between fruit of different ripeness stages generally did not differ significantly both before or after storage, although their DM content seemed to be lower in fruit harvested at 4 DAFY and higher in fruit harvested at 14 DAFY (Table 3). Also, no changes in DM content occurred in dokong during storage.

Total soluble solids (TSS) and total titratable acidity (TTA) are also presented in Table 3. It is clear that TSS in dokong significantly increased as the stage of ripeness advanced. TTA was significantly higher in fruit harvested at an earlier stage of fruit maturation (4 DAFY). Acidity was reduced thereafter and did not differ in fruit harvested between 7, 10 and 14 DAFY.

Table 2. Colour changes of dokong fruit harvested a different stages of ripeness, before and after storage for 5 days under ambient conditions (DAFY = days after fruit yellowing).

Ripeness stage (DAFY)	L*	a*	b*	Chroma (C*)	Hue angle (H°)
			After harvest		
4	58.4 ab	–1.4 a	35.2 d	35.2 c	94 d
7	61.6 b	–0.3 ab	34.5 cd	34.5 bc	92 c
10	61.6 b	+0.3 b	34.4 cd	34.4 bc	92 c
14	60.3 ab	+8.2 d	29.9 a	31.0 a	74 a
			After storage		
4	56.7 a	+1.7 c	32.0 b	32.1 a	87 b
7	57.7 ab	+1.8 c	32.5 bc	32.6 ab	87 b
10	58.1 ab	+1.7 c	32.7 bc	32.8 ab	87 b
14	56.8 a	+2.3 c	32.0 b	32.0 a	86 b

*Days after fruit yellowing
Note: Values in each column marked with the same letter of the alphabet are not significantly different at the 5% level using Duncan's multiple range test (DMRT).

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edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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This finding was in agreement with that reported by Ahmad Tarmizi et al. (1998). The increase in TSS without an increase in TTA resulted in an increase in the TSS-to-TTA ratio and led to the fruit tasting sweeter. Dokong with a TSS-to-TTA ratio of about 20 was highly acceptable in terms of taste and the fruit became sweeter as the ratio increased (Ahmad Tarmizi et al. 1998).

Some changes in TSS and TTA occurred during storage. Interestingly, TSS in fruit of 4 and 7 DAFY maturation increased from 8 and 13°Brix , respectively, to 15 and 17°Brix, respectively, after 5 days of storage under ambient conditions. The decrease in TTA however, was negligible and acid content in fruit after storage for all ripeness stages did not differ significantly. The TSS-to-TTA ratio in fruit harvested at 4 and 7 DAFY was found to increase significantly to 20 and 24, respectively, after storage. The results show that dokong harvested as early as at 4 DAFY were acceptable in terms of taste after being stored for 5 days under ambient conditions.

In the past, dokong was normally harvested from 11 days onwards after the fruit yellowing stage when all the fruit in a bunch had turned full yellow, although some growers harvested a little earlier. It is now recommended that the fruit can be harvested much earlier, about 4–5 days after the fruit yellowing stage if the fruit is to be transported to distant markets. At this stage, the whole bunch of fruit has turned yellow with 6–8 fruit per bunch still having a greenish tinge at the stylar end. The fruit harvested at this stage can be kept for at least 5 days under ambient conditions and the fruit bunch is able to turn full yellow. Fruit quality is highly acceptable as the sweetness increases due to an increase in total soluble solids and a decrease in acidity after 5 days after harvest. Fruit may be kept longer when stored at low temperatures. Duku-langsat, another species of *Lansium* can be stored for 2 weeks at 10°C (Mohd Salleh et al. 1985). Therefore, further research needs to be carried out to study the storage behaviour of dokong under low temperature conditions.

Acknowledgments

The authors gratefully acknowledge the financial assistance of the Ministry of Science, Technology and Environment for the Intensification of Research in Priority Areas funding. The authors would also like to express their appreciation to Mr Sauli Mat Yunus and Ms Norhayati Maning for their assistance in this study.

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Table 3. Firmness and chemical characteristics of dokong harvested a different stages of ripeness, before and after storage for 5 days under ambient conditions (DAFY = days after fruit yellowing, TSS = total soluble solids, TTA = total tritratable acidity).

Ripeness stage (DAFY)	Firmness (kg force)	TSS (°Brix)	TTA	TSS/TTA	Dry matter (%)
		After harvest			
4	4.69 d	8.3 a	1.18 c	7.1 a	17.9 ab
7	4.24 bc	13.4 b	0.82 ab	16.5 b	18.7 abc
10	4.08 b	18.3 e	0.84 b	22.0 c	19.8 cd
14	4.58 cd	23.4 f	0.82 ab	29.4 d	22.5 e
		After storage			
4	2.68 a	15.2 c	0.76 ab	20.3 bc	17.4 a
7	2.48 a	16.8 d	0.71 ab	23.8 cd	19.3 bcd
10	2.30 a	18.1 e	0.75 ab	24.6 cd	19.9 cd
14	2.35 a	18.5 e	0.68 a	27.5 de	20.5 d

Note: Values in each column marked with the same letter of the alphabet are not significantly different at the 5% level using Duncan's multiple range test (DMRT).

Quality assurance in agricultural produce,
edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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Quality assurance in agricultural produce,
edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
ACIAR Proceedings 100
(printed version published in 2000)

Protection of the Environment and Produce from Contamination with Pesticide Residues

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Abstract

Preventing the contamination of the environment and of agricultural produce with pesticide residues is a complex task. The design of a successful strategy demands:

- accurate information on the physical and chemical properties of agrochemicals;
- reliable research data on their fate and transport;
- simple techniques for ecological risk assessment and risks to human health;
- an economical means to monitor produce and the environment for contamination; and
- means of instituting best management practices, based on traceback of cases of contamination.

In Australia, an extensive program of research for the cotton industry has been undertaken to reduce the level of contamination by chemicals, such as endosulfan, pyrethroids, organophosphates and carbamate and other, newer chemicals, such as the benzoylphenylureas and herbicides. This has required a very comprehensive approach involving the development of new technology for monitoring pesticide residues. In this paper, by examining several case studies, we will demonstrate our approach to developing these techniques over the past 10 years. Specific topics include: the role of quality assurance in analysis; enzyme-linked immunosorbent assays (ELISAs) for specific, sensitive screening for residues; and studies of pesticide sorption and desorption from soil and transport aerially, in water and sediments in run-off. We will also consider the role of traceback to determine the cause of contamination and of fugacity modelling to carry out ecological risk assessment. The possibility that a new theory—the action resonance theory—will soon yield models of ecosystem processes allowing better regulation of the amount of contamination in ecosystems is discussed.

USING modern methods of chemical pest control, achieving an environment and produce free of significant levels of pesticide contamination is a challenging task. In this paper, we will examine some of the key factors producing risk and the measures that can be taken to reduce this risk to a minimum level. However, it must be understood at the outset that a complex strategy is needed for success to be assured.

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Unfortunately, it is almost impossible to apply pesticides in such a way that only the target pest is exposed. It is natural that chemicals applied almost anywhere in the environment will tend to be distributed to all of the surrounding environment. The rate and extent of this distribution is a complex interaction between the physical and chemical properties of the pesticide, the methods of application, environmental conditions and management practices. However, for all these factors, the key to successful environmental management always depends on accurate knowledge about these processes. Unwarranted optimism regarding risk and even gross ignorance regarding some essential features is usually the cause of serious problems that may develop.

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edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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Chemical and Physical Properties of Agrochemicals Affecting Dissipation

The main physico-chemical factors of relevance in the contamination of ecosystems and produce include those discussed below.

Solubility

Agrochemicals display a wide range of solubilities in different solvents or phases in the environment. Thermodynamically, solutes will dissolve to the greatest extent in phases where they can minimise their chemical potential and free energy. At equilibrium, the chemical potential ($\mu_{I,}$ a measure of capacity to do chemical work) reaches the same value in all phases involved in the equilibrium. Thus:

$$\mu_i = \text{constant} \quad (1)$$

This may be achieved at vastly different concentration values in different phases. In effect, this equality involves matching the quantum state transitions for molecules leaving or entering each phase. When the magnitude of the quantum of energy needed for molecular transition to a common phase (e.g. to the atmosphere as vapour) is equal, the chemical substance in each phase is said to have the same chemical potential and they will be at equilibrium with one another.

Reference texts, such as The Pesticide Manual (Tomlin 1997), contain information on laboratory studies related to solubility in different phases. These include values for $K_{ow,}$ the octanol–water coefficient, which measures the ratio of the equilibrium concentrations in octanol and water; $K_{oc,}$ the equilibrium partition coefficient in organic carbon and an aqueous solution, which will vary depending on the properties of the organic material; and $K_{d,}$ which is a measure of the partition coefficient in phases such as soil or water. Thus, $K_d = K_{aw}$ would be the distribution coefficient between air and water. Practical relationships between these may be expressed as mathematical equations and are of relevance in examining the distribution of pesticides in soil fractions. Isotherms relating the constant temperature distribution of agrochemicals dissolved or suspended in water with soil or clay, such as the Freundlich isotherm (equation 2) are also often of utility in describing their behaviour.

$$S = KCe^n \quad (2)$$

where: S = concentration sorbed on soil; Ce = equilibrium concentration on soil; and K and n are constants (Baskaran and Kennedy 1999).

The octanol–water coefficient (K_{ow}) can be used to predict the likelihood of persistence of chemicals in produce or the environment. Lipophilicity or solubility in fats indicates that a substance is non-polar, with little or no distortion of electron clouds in the molecular structure. Halogenated organic molecules have increased solubility in fats so that substances like DDT (1,1,1-trichloro-2,2-bis(4-chlorophenyl ethane)) and the cyclodienes such as endosulfan and dieldrin tend to be very strongly partitioned into fats. They have a correspondingly high $K_{ow.}$ This makes them prone to contaminate fatty foods, such as animal products like beef, dairy products and other oils. They also tend to become immobilised in soil organic matter or in sediments in aquatic systems. In general, they are also unavailable for degradation or for transfer to other phases when dissolved in fat. The case study in Australia involving chlorfluazuron (Helix©) contamination of beef in the mid-1990s (Kennedy et al. 1998) as a result of feeding cotton trash from ginning mills to livestock was eminently predictable—given that this chemical has one of the highest K_{ow} values known. Unfortunately, those with the appropriate chemical knowledge were unaware that cotton trash would be fed to stock during a drought period and were not consulted about the wisdom of this action.

Volatility

Another physical property of significance is the tendency of an agrochemical to volatilise, thus entering the atmosphere. The vapour pressure of a chemical substance in a closed space over a sample of the pure compound is one measure of the tendency of a chemical to become volatile. However, the rate and extent of volatilisation also depends on the solubility of the chemical in solid and liquid phases. Where a chemical has high solubility in soil, water or vegetation, indicating its preference for that particular medium, the chemical potential is very much reduced from that of the pure compound, and the resultant vapour pressure is also reduced. Where the solubility in soil or water is relatively low, the chemical potential, the escaping tendency and the rate of volatilisation are correspondingly increased.

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edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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Another important partition coefficient affecting volatilisation is K_{AW}, the air–water distribution coefficient mentioned above.

$$K_{aw} = \frac{C_a^s}{C_w^s} = \frac{P^s}{RT\, C_w^s} \qquad (3)$$

where: C^s indicates the saturation concentration; P^s is the corresponding vapour pressure (P^a); and $C^s{}_w$ is the solubility in water (mol/m^3). $P^s/C^s{}_w$ is known as the Henry's Law Constant (H) = $K_{aw}RT$. This constant has the physical dimensions of energy per mole and a high value indicates a high propensity to become volatile.

In Table 1, the solubility, vapour pressure and Henry's Law constants for benzene, DDT and 2,4-dichlorophenoxyacetic acid (2,4-D) are given, showing large differences in the volatilising behaviour of these three chemicals. Note that DDT has a very low solubility in water but also a very low vapour pressure. As a result, DDT has high volatility from water despite a low vapour pressure, whereas 2,4-D is mainly distributed to water rather than the atmosphere.

Chemical degradation

The chemical properties of agrochemicals also affect the rate of their dissipation and the likelihood of contamination of produce or the environment. For example, organophosphate compounds are subject to alkaline hydrolysis, usually yielding non-toxic products. Typically, toxic organophosphates have short degradation times, declining to half the original concentration in days or weeks. However, some are more stable than others. For example, chlorpyriphos is relatively long-lived, with a half-life of several months. Thus, as the pH value of soil or water rises, so does the rate of hydrolysis. Typically, chemicals subject to alkaline hydrolysis will degrade ten times faster for each increase in the pH value of one unit. Endosulfan is also subject to alkaline hydrolysis and degrades to non-toxic endosulfan diol as the pH value is raised.

Biodegradation

Many agrochemicals are subject to biodegradation. Chemicals absorbed by soil microbes may be attacked by a variety of enzymatic processes including hydrolases (e.g. phosphatases, demethylases, sulphatases etc.) and oxidases, including mono-oxygenases and conjugases. In general, oxidative processes make fat-soluble or lipophilic agrochemicals more water soluble, and more prone to further metabolism and breakdown. Some agrochemicals, such as 2,4-D, can provide sources of growth substrates for microbes, with most of the deoxyribonucleic acid (DNA) coding for genes of 2,4-D degrading enzymes being carried on transmissible plasmids. It is therefore possible to genetically engineer microbes by such transfers (Van Zwieten et al. 1995; Feng and Kennedy 1997).

Research on Fate and Transport

Despite the ability to make predictions from physico-chemical properties, no exact model of the behaviour and fate of agrochemicals in ecosystems is currently available. This is in large measure a result of the fact that their dissipation is a non-equilibrium process in which fluctuations in source strengths are at their maxima when chemicals are periodically applied and in the driving potentials causing their transport occur. Apart from the concentration at the source, a number of factors or processes may be involved in contamination of produce or the environment. These include:

- Drift during application. Depending on environmental conditions, a proportion of the agrochemicals applied either aerially or by ground application may drift onto surrounding areas—directly onto livestock or onto pasture or water. In

Table 1. Volatility of organic chemicals from the aqueous phase, showing the solubility, vapour pressure and Henry's Law constants (see text and equation 3 for full explanation).

	Molecular mass	Solubility (g/m^3)	Vapour pressure (Pa)	H	K_{AW}
Benzene	78	1 780	12 700	556	0.22
DDT	355	0.003	0.00002	2.4	9.5×10^{-4}
2,4-D	221	890	0.000056	1.4×10^{-5}	5.6×10^{-9}

Note: for benzene, C^S=1780/78=22.8 mol/m^3; H is then $P^S/C^S{}_W$ = 556; etc.

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edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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general, the intensity of drift onto pasture falls off with distance (Craig et al. 1998).

- In Figure 1, the rate of degradation of residues in green and dry pasture with time for small drop (ultra low volume—ULV) and large drop size (emulsifiable concentrate—EC) applications is shown. Thus, an interaction between the drift profile with distance and the rate of degradation, including biodegradation, is involved in this case.
- Dissipation rates on crops and in soil. Depending on the physical and chemical properties of agrochemicals, their persistence will depend on environmental factors, as well as biodegradation rates (Kennedy 1998). In the case of edible crops, the dissipation rate is a critical factor in establishing the withholding period before produce is released for marketing, direct consumption or for value-added processing. It is essential that the produce should contain concentrations below the maximum residue limits (MRLs) and it would be prudent to have a means of confirming this. Case studies for endosulfan dissipation rates in cotton production systems were presented earlier (Kennedy et al. 1998).
- Transport in run-off and infiltration. Depending on the rate of dissipation in soil or on crops, run-off water from irrigation or storms will contain different levels of pesticide residues (Kennedy et al. 1998). In general, there is a good correlation between levels on fields and those in run-off water. But the partitioning between suspended sediments and the water fraction will depend on the chemical and distribution properties of each chemical. Agrochemicals with relatively high water solubility, such as the herbicide atrazine, may have a tendency to migrate to groundwater. Obviously, knowledge of residue concentrations in run-off or groundwater is essential if secondary contamination of stock or produce is to be avoided.

Ecological Risk Assessment

The fugacity or escaping tendency for a chemical from a concentrated zone then dictates that a dispersive process will occur, utilising whatever means of transport or modes of motion that are available. Usually, such processes are explained by statistical mechanics on a stochastic basis, as a result of random fluctuations. But this purely statistical viewpoint has recently been challenged in a new general hypothesis called the 'action resonance theory'. This theory asserts that valid statistical outcomes require forceful dispersive interactions based on quantum exchange forces that cause all motion in coherent groups of sub-atomic particles called molecules. The basic dynamic explanation for such real world processes is discussed at length in a new book (Kennedy 2000) that stresses the significance of a physical property called action. Planck's quantum of action (h) is the unit value of action. In the thermodynamic sense, both the action and the entropy of chemicals and all other matter are increased as the process of dispersion occurs. Entropy is a dimensionless capacity factor indicating the amount of energy needed to continuously sustain the action of the system, easily expressed as a logarithmic function of the action (Kennedy 1983).

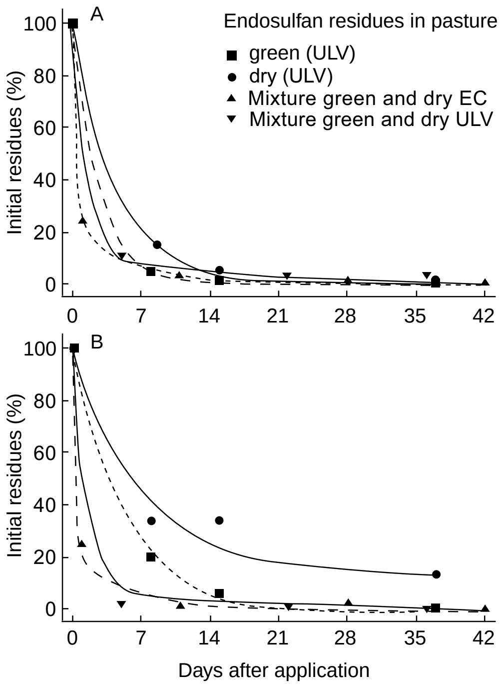

Figure 1. Endosulfan residues from drift onto pasture as a result of (A) direct spray (10 m) and (B) downwind drift (100 m). The decline with time and distance from the swathline of the aerial application for ultra-low volume (ULV) and emulsifiable concentrate (EC) on green and dry pasture is shown. The maximum concentrations for 10 m and 100 m were 50 ppm and 5 ppm, respectively.

The more macroscopic the process involving a particle or an association of particles—in the change

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of scale of interactions from nuclear to electromagnetic to gravitational—the less energy is needed to achieve the next highest action state. Consequently, nuclear processes require quanta with the highest frequency (>10^{20}/s) or rate of impulses, acting on very brief time scales with high local precision and carrying the greatest momentum and potential to develop force in the short term. Electromagnetic interactions involved in chemical changes employ quanta with intermediate magnitude on this scale (<10^{18}/s and >10^{12}/s). Gravitational processes such as those involved in transport of sediments suspended in runoff water require the coordinated dispersive action of vast numbers of quanta of low to vanishingly low magnitude. The low impulsive force provided by individual quanta is compensated for by the large density of quanta acting together. This analysis suggests that the concept of entropy as a continuous measure of disorder is misleading, since an optimised development of entropy and action is essential for the functioning of ecosystems.

The mechanism for development and evolution of all these processes is similar to that of Brownian motion, by which Einstein (1917) explained results from forces of recoil caused by the interchange of impulsive quanta of energy within molecular systems or larger particles. The impulses from such quanta act along the direction of transmission so that asymmetry of the force fields generated is possible if matter is arranged in an asymmetric fashion. Such recoil to the absorption or emission of quanta amounts to a thermodynamic force capable of inducing motion in molecules. This concept of action state has been generalised for all scales (Kennedy 2000) to provide a common forceful mechanism for a range of physical and chemical work phenomena in ecosystems as part of the action resonance theory. This will allow chemical, electrical and gravitational processes to be considered in the same model, all acting by integration to the appropriate scale of the local action exchange forces. In future, we anticipate that simplified physical action models will be developed, allowing this approach to be easily applied to many microscopic and macroscopic processes occurring in ecosystems.

In the meantime, these action exchange forces are considered as the driving force for the redistribution of agrochemicals in ecological risk assessment, modelled more traditionally using the fugacity model of Connell (1991, 1997). An ecological risk assessment of 32 pesticides which have been used in previous years on a cotton farm adjacent to a nature reserve in the Macquarie Marshes in the Macquarie River valley (see Figure 2) has been conducted (Sanchez-Bayo et al. 2000). Specifically, the impact of 18 chemicals that would be used in a new development proposed by the grower for extending the area farmed has been examined using the fugacity model—incorporating a new relative risk model (Table 2).

Calculating risk

Based on a simple quotient model, the new expression to calculate relative risk used here also considers the exposure/toxicity in each compartment. For the entire ecosystem, the relative risk (*RR*) of a chemical is the sum of its risk in each environmental compartment (RR_i) as determined by the following equation:

$$Relative\ Risk\left(RR\right) = \sum RR_i \qquad (4)$$

where i is the environmental compartment considered, and for which the risk is calculated in mathematical terms as

$$RR_i = \frac{exposure}{toxicity} = \frac{C_i\left(\sum_v P_{iv} \times V_{iv}\right) \times t_{1/2i} \times BCF}{\dfrac{LD_{50}\,ij}{\sum\left(Sij + 1\right)}} \qquad (5)$$

and C_i = the concentration of the chemical (ppb) in the compartment i;

P_{iv} = the probability of the event v in the compartment i;

V_{iv} = the volume (m^3) affected by such event v in the compartment i;

$t_{1/2i}$ = the half-life (days) of the chemical in the compartment i;

BCF = the bioconcentration factor for the chemical;

$LD_{50}ij$ = the toxicity (ppb) of the animal class j affected in the compartment i; and

Sij = the number of species of the animal class j exposed to the compartment i.

The value of $LD_{50}\,j$ is calculated as a weighted average of the estimated LD_{50}, after taking into account the number of species (n) in each group:

$$LD_{50}\,j = \sum\left(nLD_{50}\right) \qquad (6)$$

Then, the *RR* values will be specific for a particular ecosystem, since they will be comparing chemicals against all the environmental conditions as well as the probable effect that they will have on the species of that ecosystem. Because of the multiplicity of param-

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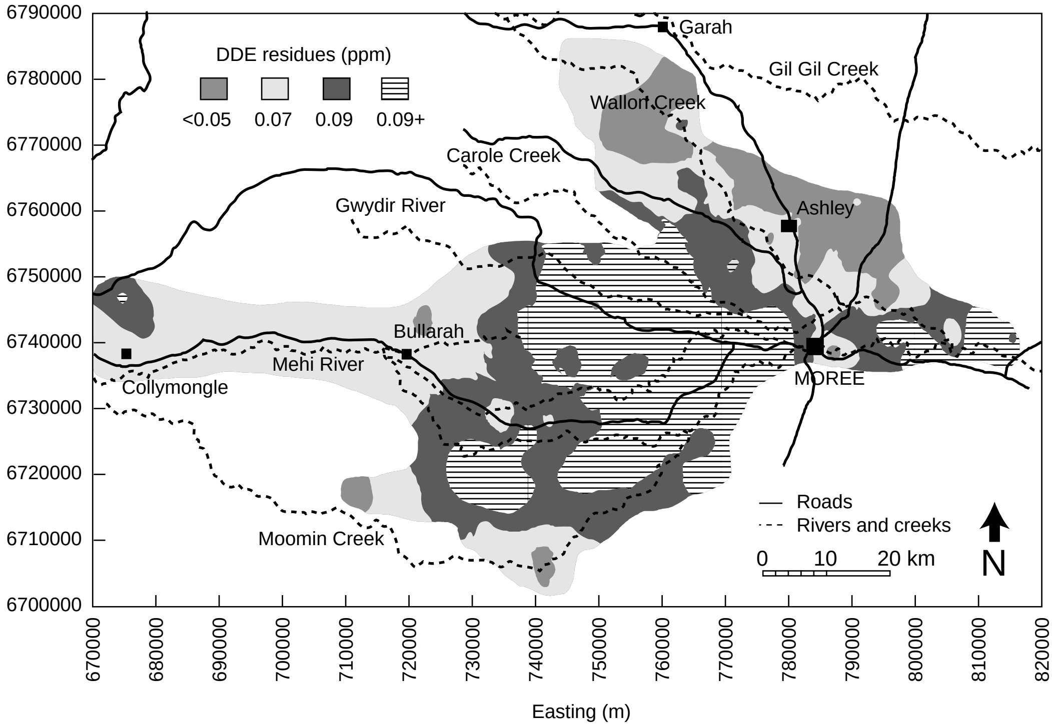

Note: DDE (1,1-bis(p-chlorophenyl)-2,2-dichloroethylene) is a breakdown product of DDT (1,1,1-trichloro-2,2-bis (4-chlorophenyl ethane)).

Figure 2. Monitoring of DDE residues in the Gwydir Valley, New South Wales, by the enzyme-linked immunosorbent assay (ELISA). Geograpical information system (GIS) profiling was established using GIS software by Dr I.O.A. Odeh performed when DDT was last sprayed in the area around 1982. Soil samples were taken in 1995–97 and represent average concentrations for 0–10 cm in the soil profile.

eters involved, the *RR* values are dimensionless and can be used as a score to rate the risk under several situations. From these calculations a relative risk rating index can be formulated for each chemical. In this ecological risk assessment, four risk-ranking categories have been established:

High risk	*RR* > 100
Medium risk	10 < *RR* < 100
Low risk	1 < *RR* < 10
Negligible risk	*RR* < 1

In normal farming situations, because of retention of all tail drain run-off, all chemicals would be contained within the farm boundaries, except for small amounts transported off-field by aerial drift. The analysis based on previous research shows that a buffer zone extending 1,400 m all around the cotton fields would capture 99.9% of any drift and volatilisation from aerially-applied chemicals, whereas a 200 m buffer would suffice to contain an equal proportion of drift from pesticides applied by ground-rig.

As shown in Table 2:

- The pesticide identified as having the highest risk within the buffer zones during the growing season under normal farming conditions is parathion-methyl, which affects mainly the soil and vegetation of the buffer zone.
- Under normal growing conditions, propargite, endosulfan and aldicarb were identified as medium-risk pesticides. Aldicarb has a risk in the farm irrigation system, whereas propargite and endosulfan in the vegetation compartment of the south-western riverine woodland—the risk of propargite involves the pasture of the neighbour's property, and—if applied aerially—a small portion of the nature reserve.

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- During winter time, however, none of the 32 chemicals are of great concern.
- Other than by drift and volatilisation, the major transport route off-farm is by floodwaters. High floods occur once in 3 years and, in this case, pesticide residues would spread over the buffer zone and downslope. Despite the dilution of residues experienced under these situations, some impact would be felt in the marshes ecosystems. Large storms, with a probability of 1/year or less, could wash chemicals from soil and vegetation, but these residues are contained within the farm irrigation system or in the reservoirs established in the buffer zone to contain stormwater run-off. In these situations, the risk of pesticides to waterbirds coming to the farm for feeding/drinking is to be considered. This approach has been generalised (Sanchez-Bayo et al. 2000) for other cases where farms may be established near areas posing risk, such as rivers and other farming enterprises.

Monitoring of Produce and the Environment

It is essential to have means of ensuring produce or the environment in which it is produced is not contaminated. This demands some system of monitoring the concentration of a large range of agrochemicals. Effective monitoring requires considerable infrastructure and a set of validated sampling and analytical protocols to ensure that reliable data are generated. A quality assurance manual for the monitoring of pesticide residues in cotton production systems is available (Kennedy et al. 1998), emphasising the need for highly skilled and experienced personnel and extensive equipment.

The possibility of using simple tests for screening purposes is becoming more feasible. This is a result of the development of testing procedures, based on techniques such as the enzyme-linked immunosorbent assay (ELISA). We describe the feasibility of such approaches separately (Lee et al., this proceedings). We have previously described the application of ELISA to environmental monitoring, pointing out how a much more comprehensive assessment of contamination can be obtained with chemicals such as endosulfan (Lee et al. 1997). The advantages of such tests can be considerable in cost and also the numbers of samples that can be analysed promptly, so that action can be taken immediately. It may also be possible to provide special advantages in such assays.

Table 2. Chemicals of high (bold) and medium risk under several scenarios.

Area at risk	Flooding scenarios		Normal scenarios	
	Summer	Winter	Summer	Winter
On farm				
Buffer zone	**Parathion-methyl** Propargite Endosulfan Chlorpyrifos -cypermethrin Bifenthrin Profenofos	Parathion-methyl Propargite	**Parathion-methyl** Propargite Endosulfan	None
Buffer zone	Propargite	Propargite	Propargite	None
Irrigation system	Dimethipin	Dimethipin	Aldicarb	None

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Table 2. (Cont'd) Chemicals of high (bold) and medium risk under several scenarios.

Area at risk	Flooding scenarios		Normal scenarios	
	Summer	Winter	Summer	Winter
Off farm				
Riverine forest and woodland	**Parathion-methyl** Propargite Endosulfan Chlorpyrifos -cypermethrin Bifenthrin Dimethipin Profenofos	Parathion-methyl Propargite	**Parathion-methyl** Propargite Endosulfan	None
Nature reserve	Propargite Dimethipin	Propargite Dimethipin	Propargite	None

For example, the ELISA test used in our research program for endosulfan actually measured the sum of the concentrations of the two isomers of endosulfan present in formulations as well as the toxic oxidative product, endosulfan sulphate, but not non-toxic breakdown products. It must be emphasised, however, that these tests cannot completely replace instrumental techniques, but are used for screening or in a complementary fashion. In practice, it is likely that samples producing positive results with ELISA or other simple tests would then be subjected to solvent extraction and analysis by gas–liquid chromatography or high-performance liquid chromatography, to obtain an accurate value or confirmation of the contamination. ELISAs are now available for a very large range of pesticides including herbicides (e.g. diuron, triazines, pyrithiobac sodium etc.) which we are applying in our fieldwork and in determining the association of pesticides with colloidal fractions suspended in irrigation or storm run-off (Crossan and Kennedy, unpublished) from cotton farms.

Traceback and Best Management Practices

The purpose of monitoring is to provide feedback on contamination. This can reduce the risk to humans and livestock and also to provide safeguards in the case of produce for export with respect to quality assurance. In order to achieve effective results from monitoring, it is essential to provide some means of traceback to the source of contamination. This will generally require a system of labelling of samples, or access to information regarding the source of batches of produce. Traceback studies have also been instituted in the Australian cotton industry in order to determine sources of contamination of livestock on nearby farms and to take steps to prevent future contamination (Kennedy et al. 1999). Keeping data for a number of years allows monitoring not only of sources of contamination, but also of the effectiveness of programs set in place to mitigate the likelihood of contamination by agrochemicals. Monitoring of riverine environments is also wise and a program has been in place in the case of the northern rivers of New South Wales used for irrigation farming for a number of years now (Cooper and Muschal 1998). Such monitoring programs, funded by both irrigation users and government, have a number of valuable features.

Best management practices on farms designed to reduce the impact of agrochemicals on produce and the environment are becoming de rigeur. The Australian cotton industry has instituted such a program over the past 2–3 years, coordinated by the Cotton Research and Development Corporation (ACGRA et al. 1997), the industry's research coordinator. This provides a practical set of interactive and continually updated measures recommended to prevent environment impacts from chemicals. This includes requirements to recirculate contaminated waters within the farming system without release to riverine systems, to minimise the degree of contamination. In addition, measures to reduce the direct impact of aerial drift by establishing downwind buffer zones of up to 1.5 km and prohibitions on spraying in unstable atmospheric conditions or inversions require compliance by aerial operators and cotton farmers. Similar programs of management are also being instituted by other industries such as rice production, the wine industry and horticultural industries. The wish to produce clean

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produce is almost universal, but it will remain necessary to provide means of monitoring the success of these measures. There may also be a small minority of 'renegade' farmers who may deliberately fail to comply with recommendations. In any case, produce which has been shown to be free of contamination should command a premium in the marketplace and the Australian dried fruit industry has set up its own monitoring program to ensure that all batches of fruit are certified as pesticide-free. Similar measures are now being adopted by the wine industry.

Conclusion

Protection of produce and the environment from pesticide contamination is a multi-faceted process requiring an integrated response involving the full range of factors considered in this paper. Neglect of even one aspect of this response can have disastrous consequences and cooperative action by personnel with the full range of expertise is essential. More research is needed to improve the current capability.

Acknowledgments

Financial support for the research work discussed in this paper from the Cotton Research and Development Corporation, the Land and Water Resources Research and Development Corporation, the Rural Credits Development Fund, the Cooperative Research Centre for Sustainable Cotton Production and the Australian Centre for International Agricultural Research (ACIAR) is gratefully acknowledged. We also wish to acknowledge the assistance of Dr I.O.A. Odeh with preparation of Figure 2, Dr Lyndal Hugo, and many other colleagues including Nazir Ahmad (Australian Water Technologies), Stephen Kimber and Lukas Van Zwieten (New South Wales Agriculture), John Skerritt (CSIRO/ACIAR) and Mark Silburn (Queensland Department of Natural Resources).

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Efficacy of Electrolysed Water as a Disinfectant for Fresh-cut Spinach

H. Izumi, T. Kiba and S. Hashimoto*

Abstract

The effect of electrolysed water on bacterial count was evaluated on freshly prepared and stored fresh-cut spinach leaves. Electrolysed water (pH 6.8), containing 15 to 50 ppm available chlorine, was generated by electrolysis of a 2.5% NaCl solution using an electrolysed neutral water generator. Trimmed spinach leaves were treated with electrolysed water containing 20 ppm available chlorine by dipping, rinsing or dipping/blowing. These treatments reduced the total microbial count (mesophilic aerobic bacteria) by 1.0 to 1.6 log_{10} colony forming units (CFU)/g when compared with untreated samples. Electrolysed water containing 50 ppm available chlorine had a stronger bactericidal effect than water containing 15 or 30 ppm chlorine, and was as effective as sodium hypochlorite solution containing 100 to 200 ppm chlorine. When the trimmed leaves were rinsed with electrolysed water containing 50 ppm chlorine and stored in normal air or 4% O_2 at 10 and 20°C, the increasing count of mesophilic aerobic bacteria was restricted when compared with the water-rinsed control. Electrolysed water did not affect the respiration rate nor surface colour of fresh-cut spinach during storage. Microbial populations increased on intact leaves stored at 0°C for 7, 14, 21 or 28 days. The electrolysed water was more effective in reducing the counts of mesophilic aerobic bacteria, psychrotrophic aerobic bacteria and coliform bacteria when the treatment was made using leaves stored for a brief period than for leaves stored for a long period.

FRESH-CUT vegetables are more perishable than intact vegetables mainly due to microbial contamination during and after processing (Brackett 1987; Watada et al. 1996; Zagory 1999). Microbial safety is of major concern in the production and distribution of fresh-cut vegetables in conjunction with the Hazard Analysis and Critical Control Points (HACCP) system (IFPA 1996). HACCP is a system of hazard prevention implemented by the food industry to produce safe food. It involves the systematic assessment of all steps involved in food manufacturing operations and the identification of those steps which are critical with respect to food safety (Willocx et al. 1994). To reduce microbiological hazards of fresh-cut vegetables, washing during processing is the only step taken to actively reduce microbial populations. A 50 to 150 parts per million (ppm) chlorine solution prepared from sodium hypochlorite has been widely used in the food industry as a disinfectant, but a high concentration of sodium hypochlorite for increased effectiveness may cause product tainting (Adams et al. 1989) as well as result in sodium residues on the product and the equipment (Ritenour and Crisosto 1996).

Alternatives to sodium hypochlorite, such as chlorine dioxide (Zhang and Farber 1996), sodium bisulfite (Krahn 1997), organic acid (Adams et al. 1989; Zhang and Farber 1996) and ozone (Nagashima and Kamoi 1997), have been studied to control microbial populations on fresh-cut vegetables. We previously reported the effect of electrolysed water on the microflora on several

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fresh-cut vegetables (Izumi 1999). Electrolysed water contains hypochlorous acid generated from the reaction of H_2O and Cl_2 produced by electrolysis of a NaCl solution of less than 10% using an electrolysed water generator. Our earlier study indicated that electrolysed water containing 15 to 50 ppm available chlorine was effective as a disinfectant for several fresh-cut vegetables, and the potential problems experienced using sodium hypochlorite—high concentration of available chlorine and sodium residue—were not of concern when using electrolysed water.

In this study, we initially determined the effect of electrolysed water on microbial populations on freshly prepared and stored fresh-cut spinach leaves in comparison to that of sodium hypochlorite. Treated, fresh-cut spinach was stored in normal air or 4% O_2, as virtually all fresh-cuts are packaged in modified atmosphere packaging (MAP). Subsequently, our research was expanded to determine the effect of electrolysed water on the microflora on cut spinach prepared from intact leaves at 0°C, because raw vegetables for fresh-cuts are sometimes several days old by the time they are processed.

Materials and Methods

Generation of electrolysed water

Electrolysed water (pH 6.8) containing 15, 20, 30 or 50 ppm available chlorine was generated by electrolysis of a 2.5% NaCl solution using an electrolysed neutral water generator, Ameni Clean (Model FJ-W25M1; Matsushita Seiko, Osaka). The generator was connected to a water faucet and the electrolysed water of each chlorine concentration was automatically provided at a rate of 4 L/min. The concentration of available chlorine was confirmed by the sodium thiosulfate titration method (Asada et al. 1981).

Sample preparation and electrolysed water treatments

Spinach (*Spinach oleracea* L. 'Sunbest' or 'Joker') leaves were freshly harvested at a farm in Wakayama City, Japan. Sub-samples of the leaves were cut to have 0.5 cm petioles using scissors. Each 50 g sample was treated with tap water as a control or electrolysed water (20 ppm available chlorine) at room temperature. The treatments included: (a) control = rinsed in running tap water at 2 L/min for 4 min; (b) rinsing = rinsed in running, electrolysed water at 2 L/min for 3 min followed by rinsing in running tap water for 1 min; (c) dipping = dipped in 500 mL electrolysed water for 3 min followed by rinsing in running tap water for 1 min; and (d) dipping/blowing = dipped in 500 mL electrolysed water while simultaneously blowing air at 25 L/min for 3 min, followed by rinsing in running tap water for 1 min. The water rinse after treatments was added because hypochlorous acid had not been approved for use as a food additive by the Japanese Ministry of Health and Welfare. The constraints on the use of electrolysed water had been waived as a special case. All samples were then centrifuged for 3 min to remove surface water.

50 g samples from a different lot were rinsed in running tap water or running electrolysed water containing 15, 30, or 50 ppm available chlorine for 4 min and centrifuged for 3 min to determine the effect of different concentrations of chlorine. A rinsing treatment using sodium hypochlorite solution containing 50, 100, 150 or 200 ppm available chlorine was also included to compare with the effect of electrolysed water containing 50 ppm available chlorine. All of the above treatments were replicated three times.

Total microbial counts (mesophilic aerobic bacteria) were made from the surface of a 10 g sample and of 10 g of macerated sample and the results expressed as $\log_{10}$ colony forming units (CFU)/g sample as previously described (Izumi and Watada 1994; Izumi 1999).

Storage of trimmed spinach leaves

Nine trimmed spinach leaves (530 g) were rinsed with tap water or electrolysed water containing 50 ppm available chlorine for 4 min and centrifuged for 3 min and then placed in a 1.5 L plastic container containing 20 mL of distilled water in a beaker to maintain high relative humidity. Three replicated samples were stored at 10 or 20°C under a continuous stream of normal air or 4% O_2 at 10 or 15 mL/min, respectively. The balance of the gas mixture for the 4% O_2 atmosphere was N_2. The carbon dioxide content of the inlet and outlet streams of each container was monitored with a CO_2 analyser (Model CD-3A; Ametek, PA) during storage. Three replicated samples of each treatment were taken periodically to measure counts of mesophilic aerobic bacteria and lactic acid bacteria in 10 g samples and surface colour (hue angle = $\tan^{-1}b^*/a^*$) with a chroma meter (Model NR-300; Nippon Denshoku, Tokyo), as previously described (Izumi et al. 1997).

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Storage of intact spinach leaves

Intact spinach leaves were packaged in 30 μm low-density polyethylene film bags and stored at 0°C for 28 days. Sub-samples were periodically removed from the bag, and leaves were cut into sections, dipped in tap water or electrolysed water containing 50 ppm available chlorine for 3 min, and then centrifuged for 3 min. After treatment, counts of mesophilic aerobic bacteria, psychrotrophic aerobic bacteria and coliform bacteria were determined from the surface of a 10 g sample and of 10 g sample homogenate. Culture media and culture conditions for determination of microbial counts were standard method agar incubated at 37°C for 48 h for aerobic mesophiles, or incubated at 7°C for 10 days for aerobic psychrophiles, and desoxycholate agar incubated at 37°C for 24 h for coliforms.

Results and Discussion

Total counts of mesophilic aerobic bacteria of untreated fresh-cut spinach were similar between the surface and macerate of the sample (Table 1), which may be due to the style and anatomy of leafy vegetables. Rinsing with tap water (control) reduced the microbial load by 1.2 $\log_{10}$ CFU/g on the leaf surface but not in the macerate, relative to untreated samples, while electrolysed water (20 ppm available chlorine) reduced the microbial load by about 1.6 $\log_{10}$ CFU/g on the surface and 1.0 to 1.4 $\log_{10}$ CFU/g in the macerate of samples. There was no difference in the bactericidal effect among the various treatments.

The concentration of available chlorine in electrolysed water had an effect on the microbial populations only on the surface of trimmed spinach leaves (Table 1). The microbial count on the surface was below the detection level (<2.4 $\log_{10}$ CFU/g) when rinsed with electrolysed water containing 15 or 30 ppm available chlorine and not detectable when rinsed with 50 ppm available chlorine.

The number of mesophilic aerobic bacteria on the surface of trimmed spinach leaves which had been rinsed with sodium hypochlorite solution (available chlorine from 50 to 200 ppm) decreased as the chlorine concentration increased (Table 1). This decrease in microorganism numbers with increased chlorine concentration has been reported with raw apples and tomatoes (Beuchat et al. 1998) and within the sodium hypochlorite solution itself (El-Kest and Marth 1988). The effectiveness of electrolysed water containing 50 ppm chlorine corresponded to that of sodium hypochlorite solution containing 100–150 ppm chlorine, which was comparable to or more effective than other chemical disinfectants (Adams et al. 1989; Zhang and Farber 1996).

The mesophilic aerobic bacterial count on cut spinach leaves treated with water or electrolysed water (50 ppm available chlorine) and stored at 10 or 20°C increased during storage at both temperatures regardless of the storage atmosphere, and was higher at 20°C than at 10°C (Table 2). The count was lower with electrolysed water-treated samples than water-treated controls during storage at 10 and 20°C except for samples stored in a 4% O_2 atmosphere at 10°C for 15 days. These results agree with those of Bolin et al. (1977) who reported that the initial microbial load of shredded lettuce influenced the storage stability of the product. Park and Lee (1995) reported that cut water-cress and onion treated with sodium hypochlorite solution containing 50–1,000 ppm and 10–100 ppm, respectively, maintained lower microbial populations than the control samples for only the first 5 days of storage at 5°C. This indicated that the effectiveness of sodium hypochlorite treatment was limited to short-term storage. Thus the residual effect of electrolysed water on fresh-cuts during storage seems to be greater than that of sodium hypochlorite. Lactic acid bacterial counts on all samples were not detectable on day 0 and were below the detection level (2.5 $\log_{10}$ CFU/g) during storage at 10 or 20°C.

Electrolysed water did not affect the respiration rate or the surface colour of trimmed spinach leaves held in normal air or 4% O_2 at 10 or 20°C (data not shown).

The mesophilic and psychrotrophic aerobic bacteria on the leaf surface and coliform bacteria in the macerate of fresh-cut spinach prepared from the stored, intact leaves increased by 1.4, 1.5, and 2.5 $\log_{10}$ CFU/g, respectively, during the 28 days of storage at 0°C (Figure 1). Electrolysed water treatment (50 ppm available chlorine) of cut spinach leaves reduced the population of all microorganisms during storage, and the reduction was greater with leaves stored for a brief period than for a long period. Perhaps the population of microorganisms on spinach stored for a long time became too great for 50 ppm chlorine to remain effective.

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Table 1. Total microbial count (mesophilic aerobic bacteria) of fresh-cut spinach treated with tap water (control), electrolysed water (EW) or sodium hypochlorite solution.

Treatment	Log_{10} colony forming units (CFU)/g	
	Surface[e]	Macerate[f]
Method[g]		
Untreated	4.2 a	4.3 a
Control	3.0 b	4.0 a
Rinsing	2.7 b	3.0 b
Dipping	2.6 b	2.9 b
Dipping/Blowing	2.6 b	3.3 b
Concentration[h]		
Control	2.9 a	4.3 a
15 ppm	<2.4 b	2.5 b
30 ppm	<2.4 b	2.7 b
50 ppm	ND	2.7 b
Sodium hypochlorite[i]		
Untreated	4.4 a	Not measured
EW(50 ppm)	2.8 cd	
50 ppm	3.6 b	
100 ppm	3.2 bc	
150 ppm	3.0 bcd	
200 ppm	<2.4 d	

a–d Means with different letters within each treatment in the same column are significantly different ($p < 0.05$).
[e] Mesophilic aerobic bacterial CFU on tissue surface.
[f] Mesophilic aerobic bacterial CFU in tissue macerate.
[g] Control = rinsing with tap water for 4 min; Rinsing = rinsing with electrolysed water for 3 min followed by rinsing with tap water for 1 min; Dipping = dipping in electrolysed water for 3 min followed by rinsing with tap water for 1 min; Dipping/Blowing = dipping and blowing air at 25 L/min in electrolysed water for 3 min followed by rinsing with tap water for 1 min.
[h] Control = rinsing with tap water for 4 min; 15 ppm, 30 ppm, and 50 ppm = rinsing with electrolysed water containing 15 ppm, 30 ppm, and 50 ppm available chlorine, respectively, for 4 min.
[i] EW(50 ppm) = rinsing with electrolysed water containing 50 ppm available chlorine for 4 min; 50 ppm, 100 ppm, 150 ppm, and 200 ppm = rinsed with sodium hypochlorite solution containing 50 ppm, 100 ppm, 150 ppm, and 200 ppm available chlorine, respectively, for 4 min.
ND = Not detectable.

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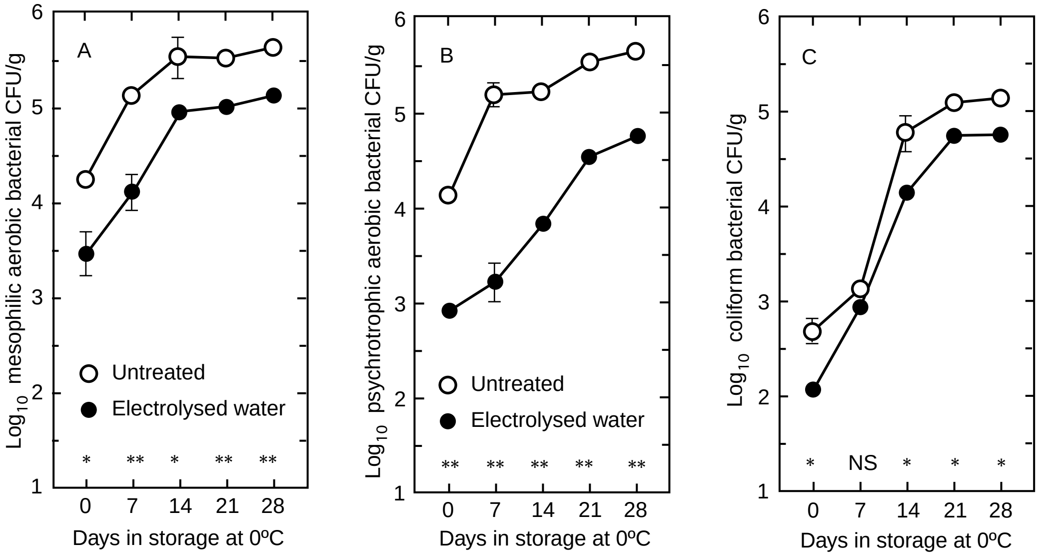

Figure 1. Counts of mesophilic aerobic bacteria (A), psychrotrophic aerobic bacteria (B) and coliform bacteria (C) of fresh-cut spinach prepared from intact leaves stored at 0°C, then dipped in electrolysed water containing 50 ppm available chlorine for 3 min. Vertical lines represent the standard error (SE). SE bars are not shown when masked by the graph symbol (CFU = colony forming units, NS = not signicant, * = significant at $p < 0.05$, and ** = significant at $p < 0.01$).

Table 2. Counts of mesophilic aerobic bacteria (MAB) and lactic acid bacteria (LAB) of fresh-cut spinach treated with tap water (Water) or electrolysed water containing 50 ppm available chlorine (EW) for 4 min and stored at 10 or 20°C under normal air or 4% O_2 conditions.

Days	Treatment	Log_{10} colony forming units (CFU)/g	
		MAB[d]	LAB[e]
10°C storage			
0	Water	2.9 a	ND
	EW	<2.5 b	ND
8	Water–air	3.9 a	<2.5 a
	EW–air	3.7 b	<2.5 a
	Water–4% O_2	3.9 a	<2.5 a
	EW–4% O_2	3.5 c	<2.5 a
15	Water–air	4.4 a	<2.5 a
	EW–air	3.9 b	<2.5 a
	Water–4% O_2	4.5 a	<2.5 a
	EW–4% O_2	4.2 a	<2.5 a

abc Means with different letters within each day in the same column are significantly different ($p < 0.05$).
[d] Mesophilic aerobic bacterial CFU in tissue macerate.
[e] Lactic acid bacterial CFU in tissue macerate.
ND = Not detectable.

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Table 2. (Cont'd) Counts of mesophilic aerobic bacteria (MAB) and lactic acid bacteria (LAB) of fresh-cut spinach treated with tap water (Water) or electrolysed water containing 50 ppm available chlorine (EW) for 4 min and stored at 10 or 20°C under normal air or 4% O_2 conditions.

Days	Treatment	Log_{10} colony forming units (CFU)/g	
		MAB[d]	LAB[e]
20°C storage			
0	Water	3.9 a	ND
	EW	< 2.5 b	ND
3	Water–air	5.4 a	< 2.5 a
	EW–air	3.6 c	< 2.5 a
	Water–4% O_2	4.9 b	< 2.5 a
	EW–4% O_2	3.8 c	< 2.5 a
5	Water–air	6.6 a	< 2.5 a
	EW–air	6.1 b	< 2.5 a
	Water–4% O_2	6.5 a	< 2.5 a
	EW–4%O_2	5.7 b	< 2.5 a

abc Means with different letters within each day in the same column are significantly different ($p < 0.05$).
[d] Mesophilic aerobic bacterial CFU in tissue macerate.
[e] Lactic acid bacterial CFU in tissue macerate.
ND = Not detectable.

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Rapid Analytical Techniques for Pesticide Residues in Food

A. Pasha*

Abstract

Pesticide residues encountered in agricultural produce are often above permissible limits, posing health hazards. They is also one of the major problems in international trade. Pesticide residues are analysed by conventional methods like gas chromatography and high performance liquid chromatography (HPLC) which are time-consuming and need trained personnel and expensive equipment. Elaborate sample preparation, clean-up and a low throughput of 4–5 samples/day are the main disadvantages of these methods. Hence there is need to develop simple and rapid alternatives to these classical methods. Enzyme-linked immunosorbent assay (ELISA) is suggested as an alternative technique, but it can give false positive and negative results due to matrix interference and responds to structurally similar compounds.

This paper describes simple and rapid chemical-based methods for analysis of various pesticide residues. Sensitive reagents like N,N-diphenylbenzidine, 4-amino-N,N-dimethylaniline, and o-tolidine were developed earlier for organochlorine, organophosphate and pyrethroid insecticide residues. Highly sensitive reagents were also developed by the author for the analysis of benzimidazole fungicides like carbendazim and benomyl and also thiram residues.

N-bromosuccinimide, N-bromo-1,2-benzisothiazol-3-(*2H*)-one-1,1-dioxide and copper (*I*) thiocyanate were used to determine these fungicide residues using a colorimetric method. Fungicide residues as low as 20 ng could be detected on paper strips prepared from some of these reagents using a densitometer. A new reagent, 1,3-dibromo-5,5-diphenyl-(*3H,5H*)-imidazol-2,4-dione, is now developed to analyse residues of benzimidazole fungicides on fruits and vegetables. 2-aminobenzimidazole (2-AB) obtained from these fungicides under different conditions reacts with the reagent to give a product having λ_{max} at 450 nm. 2-AD forms brick-red and purple coloured zones instantaneously on paper strips containing N-bromo-1,2-benzisothiazol-3-(*2H*)-one-1,1-dioxide and 1,3-dibromo-5,5-diphenyl (*3H,5H*)-imidazol-2,4-dionewith a minimum detectable limit of 20 ng.

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Quality assurance in agricultural produce,
edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
ACIAR Proceedings 100
(printed version published in 2000)

Effects on the Organoleptic Quality of Arabica Coffee Beans Processed for Export when Pulping is Delayed in Papua New Guinea

A.J. Kuri*

Abstract

Green bean coffee produced from cherries pulped on the same day of harvest and parchment which was soaked was rated the best in terms of the final raw bean, roasted bean and cup taste qualities. The quality of the green beans progressively deteriorated each day the cherries were not pulped from the day of harvest.

Cherries pulped on the fourth day after harvest produced green beans that were rated low and their quality differed significantly ($p < 0.05$) from those produced from cherries pulped on the day of harvest.

Soaking the cherries prior to pulping had an adverse effect on the final quality of the green beans produced for export, caused by the aqueous environment, and differed significantly ($p < 0.005$) in their total scores for the raw bean, roasted bean and cup taste quality.

Soaked parchment produced superior quality coffee compared to unsoaked parchment and differed significantly ($p < 0.001$) in the total scores for the raw bean, roasted bean and cup taste. The results confirmed that two-stage fermentation of arabica coffee when 'wet processed' produces a superior quality coffee.

PAPUA NEW GUINEA has faced quality problems with their arabica coffee with overseas buyers over the years, which have been caused, in part, by delays in pulping the cherries. Hence, it has been recommended to farmers that they pulp on the same day as harvesting to maintain the final quality. However, pulping on the day of harvest can be delayed for the following reasons:

- limitations in transport due to bad road conditions or no vehicles;
- limited availability or capacity of processing facilities, pulpers and fermention vats;
- involvement of farmers in other communal activities that may prevent them from pulping the cherries on the day of harvest; or
- unexpected breakdown of processing equipment and transport vehicles.

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Each day that pulping is delayed, the quality of the coffee beans is adversely affected. This study was undertaken to evaluate the effects on the organoleptic quality of arabica coffee beans processed for export when pulping is delayed in Papua New Guinea.

Further to that, the effects on the total quality of the green beans when cherries and parchment were soaked in water as compared to those not soaked for the tested coffee were evaluated. The soaking tests were carried out to see if the final bean quality could be improved by soaking in cherry form prior to pulping or in parchment form prior to drying.

Thus the objective was to evaluate the organoleptic quality of 'raw beans', 'roasted beans' and 'cup taste' when:

- pulping was delayed for up to 6 days after harvest;
- the cherries were soaked in water, compared to those not soaked, before pulping; and
- washed parchment was soaked in water and compared to parchment which was not soaked.

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Materials and Methods

Materials and equipment

a) 240 kg of fully ripe and hand-sorted cherries of Coffea arabica ‘Arusha’ were harvested from the seed plots at the Coffee Research Institute in Aiyura, Papua New Guinea.
b) 1 × coffee pulper (motorised Bentell Novo Drum Pulper)
c) 1 × Agritech Sinar 6060 moisture analyser
d) 1 × Probat-Worick sample coffee roasting machine
e) coffee tasting cups, table, spoons, and sample trays
f) 1 × Probat sample grinder
g) 24 × plastic trays with holes made in them for use as fermentation vats

Methods

Cherries were sorted by hand to remove overripe, under-ripe, dead, and insect damaged beans, then weighed into 24 × 10 kg units. Each day, 4 × 10 kg of cherries were pulped. For those to be pulped after day 1, half of the sample (2 × 10 kg) was soaked in water while the other half (2 × 10 kg) was left in the open. When the samples were pulped, parchment samples from each of the four sets of 10 kg samples were fermented separately in their own vats. An overview of the process is shown in Figure 1.

The fully fermented parchment for each day’s pulping was washed clean after an average of 34 h. From the two sets of 10 kg of cherries soaked, one set of clean parchment was soaked in clean water while the other set was sun-dried. Again, from the two sets of 10 kg of unsoaked cherries, one set of clean parchment was soaked while the other was sun-dried. This process was repeated for all of the six days’ pulping.

During sun-drying, the moisture content was reduced to 10.5% and the fruit hulled to obtain the green bean as the final product. Green beans were roasted at 180–200°C for a medium roast using a Probat-Werke sample-roasting machine. In order to minimise the effects of the degrees of the roast and brewing formula (ICO 1991), all the samples were carefully roasted to medium roast.

The roasted and cooled samples were finely ground with a sample grinder and prepared for cup tasting in the usual commercial manner. For one coffee sample, three cups were prepared using standard coffee-tasting cups. Ground coffee was measured using the standard scooping spoons (10 g) and tasting cup (30 mL). That is, cups were prepared at a ratio of 1:3 coffee to water.

A score was given on a standardised form, designed for the trial using the same vocabulary as used to describe coffee in Papua New Guinea as well as internationally (see Appendix 1). The score given by the taster for each quality parameter was an average of the three cups tasted. The total quality for the ‘raw beans’, ‘roasted beans’ and ‘cup taste’ was evaluated on a number of parameters assessed for each of the samples. The score given by the taster as a measure of the quality was based on the understanding that the lower the score, the better the quality.

Statistical package for the analysis

The statistical analysis for the measured parameters was carried out using the Genstat 5 Release 3.2 (PC/Windows 95), Copyright 1995, Lawes Agricultural Trust (Rothamstead Experimental Station). Analysis of the variance for each parameter was tabulated as shown in Appendix 2.

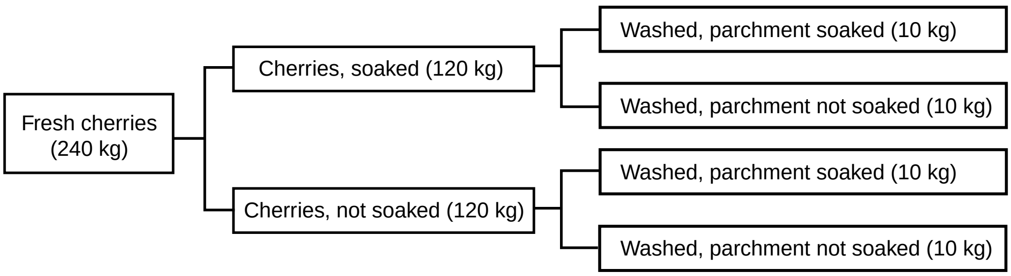

Figure 1. Method of sample preparation—process flow for treatment of the 240 kg batch of cherries. 40 kg of cherries were pulped each day for the four treatments as shown.

Results and Discussion

Effects of delayed pulping on the raw bean quality

The raw bean quality declined from its original state from the day of harvest as pulping was delayed (Figure 2A). The mean score of cherries pulped on day 4 (5.06), day 5 (4.86) and day 6 (4.81) were significantly higher ($p = 0.05$) than the mean score (3.97) of cherries pulped on the same day of harvest (Tables 1A and 1B).

The cherries which were not soaked produced better raw bean quality compared to the soaked cherries (Figure 2B). For the unsoaked cherries there was a gradual decline in the raw quality from day 1 to day 3 and then a significant decline ($p < 0.05$) from day 3 to day 4. The scores for the soaked cherry indicated that there was a significant decline in the quality from day 1 to day 2 which improved on day 3 but declined on day 4.

The scores for soaked parchment were comparatively lower than those for parchment which was not soaked, indicating that soaking parchment has a positive effect on the raw quality (Figure 2C). The difference between the soaked and unsoaked parchment was not significant for the cherries pulped on days 2 and 3 but differed significantly ($p = 0.05$) for all the other days.

Effects of delayed pulping on the roasted bean quality

There was notable negative trend from its intrinsic quality from day 1 to day 2 and from day 3 to day 4, indicating a progressive decline in quality (Figure 3A). Mean scores for the cherries pulped on day 4 (6.78) and day 6 (6.64) were significantly ($p = 0.05$) higher than the mean score (5.75) of cherries pulped on the day of harvest (Tables 2A and 2B).

Soaking harvested cherries had an adverse effect on the roasted bean quality, especially those pulped on days 2, 4 and 5 as compared to the quality of cherries which were not soaked (Figure 3B).

The mean score of the soaked cherries pulped on day 3 (6.00) was significantly lower ($p < 0.05$) than that of day 2 (6.67), while that of day 6 (6.39) was also significantly lower ($p = 0.05$) than the score of day 4 (7.17), indicating possible osmosic behaviour of soluble solids in the beans. There was a progressive decline in quality for unsoaked cherries from day 1 to

Table 1A. Mean scores for raw bean quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	3.97	4.22	3.72	3.72	4.22
Day 2	4.53	5.11	3.94	4.44	4.61
Day 3	4.36	4.67	4.06	4.33	4.39
Day 4	5.06	5.17	4.94	4.83	4.28
Day 5	4.86	4.89	4.83	4.39	5.33
Day 6	4.81	5.11	4.50	4.33	5.28
Overall means	4.60	4.86	4.33	4.34	4.85

Table 1B. Statistics for raw bean quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference f means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.250	0.353	0.697	36	190
Cherry soaking test	0.144	0.204	0.403	108	190
Parchment soaking test	0.144	0.204	0.403	108	190

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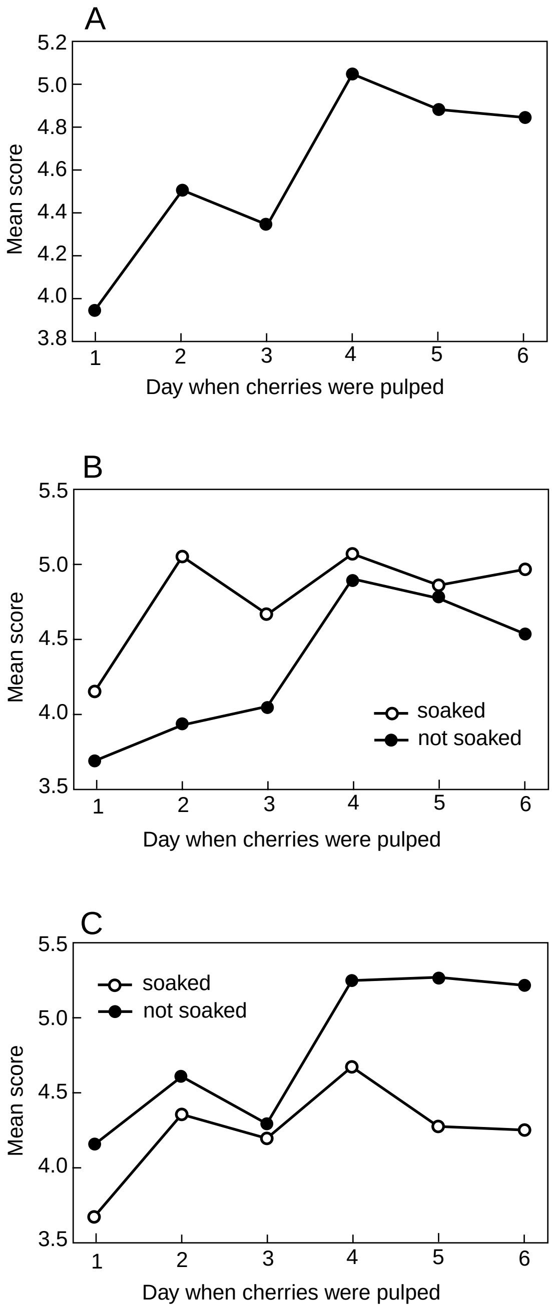

Figure 2. Effects on raw bean quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

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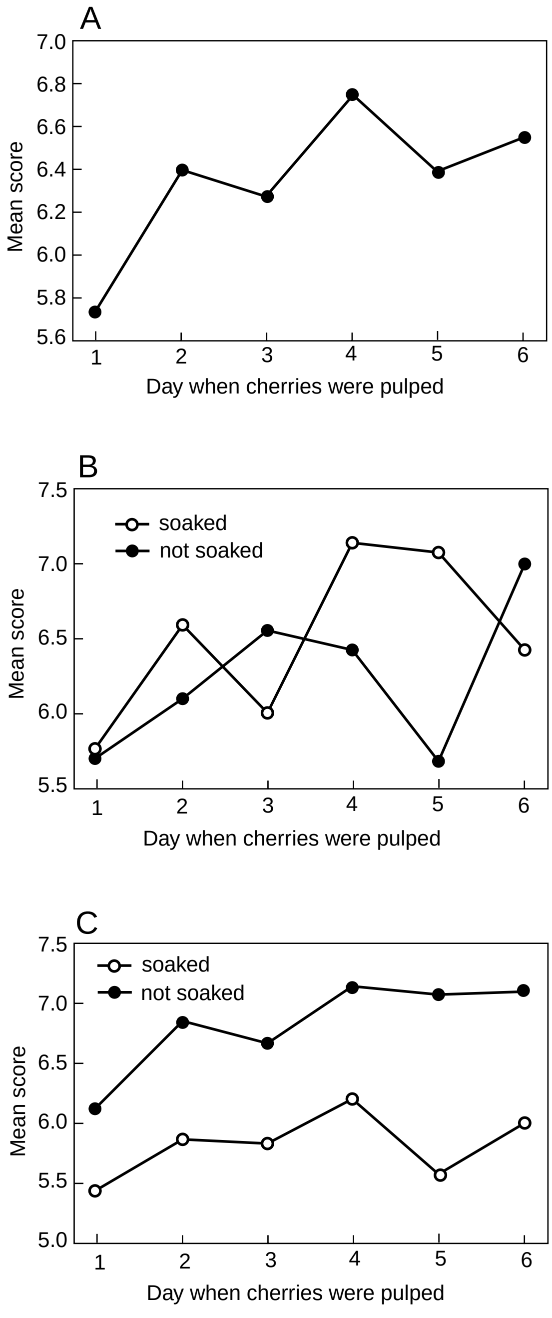

Figure 3. Effects on roasted bean quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

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day 3. Those pulped on day 5 scored the lowest, indicating a much improved roast quality which differed significantly ($p < 0.05$) from day 4 and 6.

Soaking washed parchment improved the roasted bean quality and there was a notable difference between the soaked and unsoaked parchment (Figure 3C). Mean scores for the soaked parchment were significantly lower ($p = 0.001$) that for parchment which had not been soaked, indicating an improvement in roast quality. There was a significant ($p < 0.05$) decline in quality from day 1 to day 2 and from day 3 to day 4 but also a significant improvement ($p < 0.05$) from day 4 to day 5.

Effects of delayed pulping on cup taste quality

The cup taste quality declined progressively each day that cherry pulping was delayed from the day of harvest (Figure 4A). The mean scores of the cherries pulped on day 3 (7.31) and later were significantly higher than the mean score (6.19) for the cherries pulped on the day of harvest (Tables 3A and 3B). The decline in quality was notable from day 1 to day 2 and was significant ($p = 0.05$) from day 3 onwards. The cup taste quality for the cherries pulped on day 5 and 6 did not vary significantly.

The soaked cherries had higher mean scores compared to the cherries which were not soaked (Figure 4B) and the cup taste quality differed significantly ($p < 0.001$) for the cherries pulped on days 2 and 4. The decline in cup taste quality for the soaked cherries per day was significant ($p = 0.05$) from days 1 to 4, but those pulped on days 5 and 6 improved slightly. There was a significant ($p = 0.05$) progressive decline in the cup taste quality per day up to day 6 when pulping was delayed for the unsoaked cherries.

The soaked parchment produced a better cup taste quality compared to the unsoaked parchment with significantly ($p = 0.005$) lower mean scores (Figure 4C).

Table 2A. Mean scores for roasted bean quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	5.750	5.779	5.722	5.389	6.111
Day 2	6.389	6.669	6.111	5.889	6.889
Day 3	6.250	6	6.500	5.833	6.667
Day 4	6.778	7.167	6.389	6.333	7.222
Day 5	6.389	7.111	5.667	5.667	7.111
Day 6	6.639	6.389	6.889	6.111	7.167
Overall means	6.366	6.519	6.213	5.870	6.861

Table 2B. Statistics for roasted bean quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference f means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.2420	0.3422	0.6750	36	190
Cherry soaking test	0.1397	0.1976	0.3897	108	190
Parchment soaking test	0.1397	0.1976	0.3897	108	190

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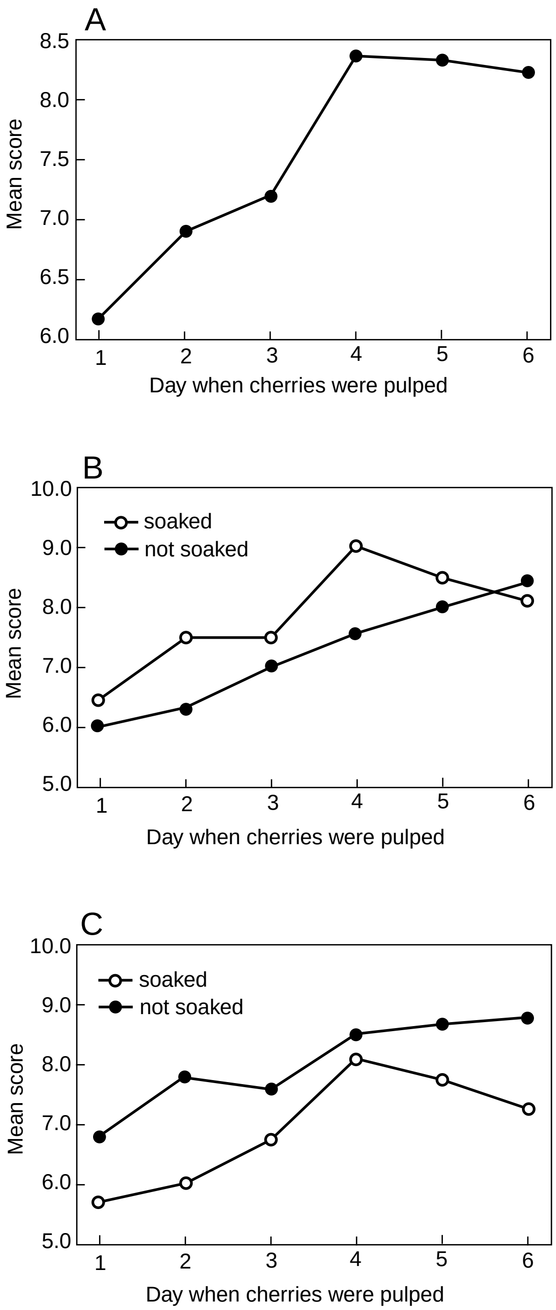

Figure 4. Effects on cup taste quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

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The cup taste quality declined from day 1 to day 2, and significantly (p = 0.05) from day 3 to 4 for the soaked parchment. The changes in the cup taste quality of the unsoaked parchment were significant from day 1 to day 2 and from day 3 to day 6.

Effects of delayed pulping on total quality

The total quality declined progressively each day that pulping of the cherries was delayed from the day of harvest (Figure 5A). According to the scores, the difference in quality between the days was significant (p = 0.05) from day 1 to day 6 (Tables 4A and 4B). There was a increased decline in the quality between days 1 and 2 and days 3 and 4.

The soaked cherries had higher scores than those not soaked from days 1 to 5, indicating that soaking the cherries when pulping was delayed had an adverse effect on quality (Figure 5B). The soaked cherry quality declined from day 1 to day 2, improved from day 2 to day 3, declined from day 3 to day 4, and then improved on day 5 and day 6, indicating osmosic behaviour induced by the fluid environment. There was a gradual loss in quality from days 1 to 6 for cherries that were not soaked.

The soaked parchment scores were significantly (p < 0.001) lower than those of the unsoaked parchment, indicating better quality of the former (Figure 5C). Soaking parchment after being washed clean improved the quality of the raw beans, roasted beans, cup taste, and the overall total quality of the product very markedly.

Conclusions

1. The intrinsic organoleptic quality of the green bean product declined after the day of harvest and to an increasing degree after the third day of delayed pulping.
2. The raw bean and roasted bean quality declined between day 1 and day 2, and more dramatically from day 3 to day 4, when cherry pulping was delayed.
3. The cup taste quality declined each day that pulping was delayed and very significantly after day 3. These results are generally in agreement with Devonshire (1956) and Robinson (1964) who reported that foxy beans, which give colour to the parchment and produce a fruity or sour cup taste, are from coffee beans fermented in cherry form.

Table 3A. Mean scores for cup taste quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	6.19	6.39	6	5.72	6.67
Day 2	6.94	7.50	6.39	6.06	7.83
Day 3	7.31	7.56	7.06	6.89	7.72
Day 4	8.33	9.11	7.56	8.17	8.50
Day 5	8.28	8.67	7.89	7.78	8.78
Day 6	8.14	8.00	8.28	7.33	8.94
Overall means	7.53	7.87	7.19	6.99	8.07

Table 3B. Statistics for cup taste quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference f means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.297	0.420	0.820	36	190
Cherry soaking test	0.171	0.243	0.478	108	190
Parchment soaking test	0.171	0.243	0.478	108	190

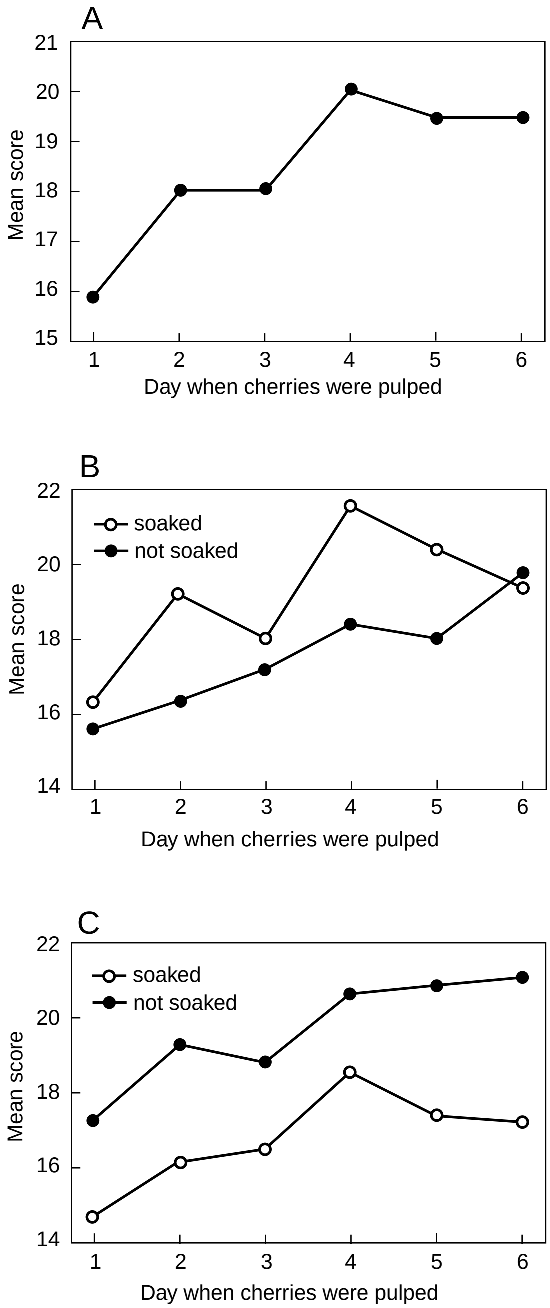

Figure 5. Effects on overall total coffee quality of (A) delayed pulping, (B) soaking of cherries and (C) soaking of parchment. Note that in the scoring system used, the lower the score, the better the quality.

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4. There were noticeable differences in quality between the soaked and unsoaked cherries, with the soaked cherries producing poorer raw bean, roasted bean and cup taste quality.
5. The soaked parchment produced a better quality coffee which was favourably scored by the tasters and differed significantly ($p < 0.001$) from the unsoaked parchment. Brownbridge and Wootton (1965) reported that arabica coffee produced from soaking of washed parchment was superior in quality compared to that which had not been soaked. These results show that under Papua New Guinea conditions, arabica coffee produced as such can also be of superior quality.

Acknowledgments

Many thanks to Mr Kilson Walawia and Mrs Josephine Wamp for their kind assistance in sorting out the data and compiling the report. I also thank Mr Anton Buro, Mr David Nema and Mr David Rumbarumba for being part of the tasting panel. Mr Pamenda Talopa's input into statistical analysis of the data is also appreciated.

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Table 4A. Mean scores for total quality.

Day of pulping	Main effects	Effect of cherry soaking		Effect of parchment soaking	
		Soaked	Not soaked	Soaked	Not soaked
Day 1	15.92	16.39	15.44	14.83	17.00
Day 2	17.86	19.28	16.44	16.39	19.33
Day 3	17.92	18.22	17.61	17.08	18.78
Day 4	20.17	21.44	18.89	19.33	21.00
Day 5	19.53	20.67	18.39	17.83	21.22
Day 6	19.58	19.50	19.67	17.78	21.39
Overall means	18.50	19.25	17.74	17.20	19.79

Table 4B. Statistics for total quality mean scores (using the Genstat Statistical software, where: e.s.e. = standard error of means; s.e.d = standard error of difference f means; l.s.d. = least significant difference; Rep = replications; and d.f. = degree of freedom).

Treatment	e.s.e	s.e.d	l.s.d.	Rep	d.f.
Delayed pulping test	0.539	0.763	1.508	36	190
Cherry soaking test	0.311	0.440	0.869	108	190
Parchment soaking test	0.311	0.440	0.869	108	190

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Appendix 1. Assessment form used by quality tasters (faq = fair average quality).

	Raw			Roast			Liquor		
	Size	Colour	Quality	Type	C/cut[a]	Quality	Body	Acidity	Flavour
Score	a	b	c	d	e	f	g	h	i
1	large	bluish green	v/good	bright	white	v/good	full	sharp	v/good
2	medium	greyish green	good	ordinary	brownish	good	medium	medium	good
3	mixed	green	faq	dull	mixed	faq	light	light	faq
4	small	discoloured	poor		dull	poor	lacking	lacking	poor
5			v/poor			v/poor			v/poor

Classification													Range	Class	Quality
Attribute	a	b	c	d	e	f	g	h	i	Total	Class	phn[b]	9–11	1	excellent
Score													12–14	2	very good
													15–17	3	good
													18–21	4	faq
													22–26	5	faq to poor
													27–32	6	poor
													33–39	7	very poor

[a] C/cut = centre-cut (describes the split in the middle of a coffee bean. The cleanliness of the centre-cut of a roasted coffee bean is used to assess the manner by which the beans were processed)

[b] phn = phenolic (a flavour character)

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Appendix 2A. Analysis of variance—raw bean quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	27.440	13.722	6.10	
Day pulped	5	27.875	5.575	2.48	0.033
Soaked cherries	1	15.042	15.042	6.69	0.010
Soaked parchment	1	14.005	14.005	6.23	0.013
Day pulped*Soaked cherries	5	6.356	1.331	0.59	0.706
Day pulped*Soaked parchment	5	6.356	1.271	0.57	0.726
Soaked cherries*Soaked parchment	1	4.449	4.449	1.98	0.161
Day pulped*Soaked cherries*Soaked parchment	5	8.912	1.782	0.79	0.556
Residual	190	427.22	2.249		
Total	215	537.958			

Appendix 2B. Analysis of variance—roasted bean quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	7.065	3.532	1.68	
Day pulped	5	22.968	4.594	2.18	0.058
Soaked cherries	1	5.042	5.042	2.39	0.124
Soaked parchment	1	53.005	53.005	25.15	<0.001
Day pulped*Soaked cherries	5	26.486	5.297	2.51	0.031
Day pulped*Soaked parchment	5	2.856	0.571	0.27	0.929
Soaked cherries*Soaked parchment	1	16.116	16.116	7.65	0.006
Day pulped*Soaked cherries*Soaked parchment	5	8.079	1.616	0.77	0.575
Residual	190	400.491	2.108		
Total	215	542.106			

Appendix 2C. Analysis of variance—cup taste quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability).

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	9.954	4.977	1.57	
Day pulped	5	135.079	27.016	8.51	<0.001
Soaked cherries	1	24.671	24.671	7.77	0.006
Soaked parchment	1	63.375	63.375	19.96	<0.001
Day pulped*Soaked cherries	5	17.968	3.594	1.13	0.345
Day pulped*Soaked parchment	5	12.708	2.542	0.80	0.551
Soaked cherries*Soaked parchment	1	2.042	2.042	0.64	0.424
Day pulped*Soaked cherries*Soaked parchment	5	24.597	4.919	1.55	0.177
Residual	190	603.380	3.176		
Total	215	893.773			

Appendix 2D. Analysis of variance—total quality (d.f. = degrees of freedom, s.s. = sum square, m.s. = mean square, v.r. = variance ratio, and F pr. = frequency probability)

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Replications	2	45.06	22.53	2.15	
Day pulped	5	447.47	89.49	8.55	<0.001
Soaked cherries	1	123.00	123.00	11.75	<0.001
Soaked parchment	1	360.67	360.37	34.42	<0.001
Day pulped*Soaked cherries	5	66.36	13.27	1.27	0.280
Day pulped*Soaked parchment	5	32.32	6.46	0.62	0.687
Soaked cherries*Soaked parchment	1	11.12	11.12	1.06	0.304
Day pulped*Soaked cherries*Soaked parchment	5	96.91	19.47		
Residual	190	1989.38	10.47		
Total	215	3172.00			

Quality assurance in agricultural produce,
edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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Improvement of Quality of Apples in Shanxi Province, China

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Abstract

In the past six years in Shanxi Province there have been extensive plantings of fruit trees (particularly apples), but the postharvest system is largely undeveloped. This report describes the results of a project on postharvest systems development, intended to develop and deliver an educational training program on the development of fruit quality assurance systems, and to develop a framework for fruit total quality management systems for one fruit crop in China. After visits by the two collaborating postharvest research groups in China and New Zealand it was agreed to hold a workshop in Shanxi, and the objectives were carefully defined.

The New Zealand team presented a five-day workshop to 37 selected representatives of local growers and support industries. A workshop manual was prepared in English and Chinese.

Before, during and after the workshop, discussions took place between the New Zealand team and the local agricultural development bureau representatives. At the conclusion of the workshop, a summary of the findings and recommendations from the workshop were completed and signed by all involved. Pre and post workshop questionnaires and other evaluation techniques were used in order to evaluate the effectiveness of the workshop. These showed that we had brought about a clear change in attitude of delegates towards recognising the value of postharvest factors, and as a result it was decided to proceed immediately with the formation of a growers' association to focus on developing a quality management system for apples. Establishment of a marketing effort was identified as a key task of the association.

There was a need for research, testing, and advisory systems to be established to enable growers to make continuous improvements to their pre and postharvest systems. A major improvement in infrastructure and in facilities for postharvest systems and quality management of apples should be achieved.

IN CHINA, fruit production has increased dramatically over the past ten years, and in the southern part of Shanxi Province fruit has become a major income source for farmers. However quality control, and postharvest handling and storage techniques are still at a very early stage of development. There is cool-storage capacity for less than one-third of the current apple production, resulting in the need to sell fruit at harvest-time. Considerable gains in quality and profitability could be achieved if modern postharvest technology was used by the industry.

In New Zealand, on the other hand, postharvest technology is already at a very sophisticated state of development, with major export markets being supplied with high quality product. Improvements in product quality through quality management systems are known to be effective in adding market value to fresh product, and hence to increase the financial return to growers. In addition, quality improvement reduces environmental impact through a reduction in the amount of poor quality product which is shipped and ultimately requires disposal in the marketplace when it cannot be sold.

Shanxi Province lies 1,000 km south-west of Beijing. It is one of the poorest provinces in China. During the project formulation stages, the Shanxi government officials stressed that their production was market driven and that they sought a high yield of high quality fruit. Furthermore they recognised the need for substantial training in postharvest systems in order to meet international standards.

One of the main apple production areas is in Yun Cheng District. This district covers the south-western

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corner of Shanxi. Apples have been grown in the district on a very small scale since 1932. However, with the reformation of agricultural policies there has been a significant increase in the area occupied by fruit trees (Tables 1 and 2). The main city of the district (Yun Cheng City) has a population of 530,000; those directly involved in agriculture and agricultural processing number 440,000. The officials estimated that 50% of those involved in agriculture and agricultural processing are engaged in fruit production and processing. The labour force associated with the fruit production and processing includes 130,000 women.

Project Initiation

The study arose as a result of an ongoing interaction between the China Agricultural University and Massey University. The project was conducted in four phases. First, linkages were established between two postharvest research groups in China and New Zealand with complimentary skills, together with contacts with agricultural development managers in Shanxi Province. This team completed the initial proposal and established funding for the project, and remained active in project management throughout the study.

From the beginning of the work, three issues became immediately obvious:

(1) there were substantial new plantings of fruit which are now coming into peak production—once full production was achieved there would be a substantial increase in the volume of fruit to be moved to market;

(2) in Shanxi, there was a dearth of knowledge concerning quality assurance in the postharvest system; and

(3) in order to realise the economic potential of the volume of fruit which would be produced in the future, a framework for fruit quality assurance was essential for the Shanxi producers.

At this stage the objectives were defined by the team as follows:

- to develop and deliver an educational training program on the development of fruit quality assurance systems; and
- to develop a framework for fruit total quality management systems for apples.

Table 1. Details of Shanxi Province and Yun Cheng District.

Parameters	Shanxi Province	Yun Cheng District
Area (‘000 ha)	15 000	1 400
Population (‘000)	33 000	4 510
Rural population (‘000)	3 930	
Arable land (‘000 ha)	4 000	610
Fruit production area (‘000 ha)	175	
Apple production area (‘000 ha)	142	
Fruit production 1999 (‘000 t)	1 500[a]	300[a]
Annual rainfall (mm)	400 (West) 600 (East)	
Temperatures	–18° to +40°C	Average: 11.5°C

[a] Estimated

Table 2. Fruit tree plantings in Yun Cheng City, 1995.

Fruit type	Variety	Area planted (ha)
Apples	‘Fuji’	24 000
	‘New Red Star’	4 300
	‘Qin Guan’	4 000
Pears		540
Peach		660
Apricot		530
Grapes		660

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These objectives were subsequently affirmed in the intermediate stages of the study.

A proposal was presented to the New Zealand Asia Development Aid Foundation, a government organisation within the New Zealand Ministry of External Relations and Trade. After appropriate modifications the project was approved in 1997.

Methodology

Following funding approval, the New Zealand team visited Shanxi Province and completed an assessment of the current state of the quality systems used for fruit handling. This visit involved inspection of postharvest handling facilities and orchards in four counties in southern Shanxi Province. Discussions took place between the New Zealand team and representatives of the Shanxi Agricultural Development Bureau. As a result of discussions during this visit, specific requests for information, and the objectives of the proposed workshop (phase 4), were established in consultation with the Chinese team (Studman 1997).

In the next phase of the project three representatives of the Chinese counterparts visited New Zealand, and discussed postharvest handling systems with growers, cool-store operators, industry representatives, Crown Research Institutes, and researchers at Massey University. During this period, further discussion took place to define more clearly the nature of the workshop, details of participants, and identification of target groups for the development of the project after the workshop.

In the final phase of the project, the New Zealand team visited Yun Cheng City and presented a five-day workshop to selected representatives of local growers and support industries.

Project Implementation

Preliminary visits

The initial visit of the New Zealand team took place in October 1997, and was designed to coincide with the harvesting period. Four counties in the Yun Cheng District were visited (Studman 1997).

During the visits, we spoke to several growers, cool-store operators, and government officials from the Fruit Enterprises Bureau on the problems they are currently experiencing and which they would like further information about during the workshop in 1998. Problems identified included aspects of fruit production and postharvest handling, quality assurance, export marketing, and finance.

Discussions were also held with Provincial government officials and staff from Yun Cheng District Fruit Enterprises Bureau to assist in formulating the topics to be covered during the workshop in 1998. The topics identified included the following:

- new types of agro-chemicals, application methods and regulatory standards;
- quality standards—what are they?
- equipment and measurement techniques for fruit quality;
- implementation of a quality assurance system—the people involved and their tasks (i.e. organisation framework required);
- the role of research and development (R&D);
- new production and postharvest techniques to assist in meeting export standards;
- pre-cooling and extending storage and shelf life;
- food safety—criteria and measurement; and
- overview of the New Zealand fruit industry —production, postharvest handling, and marketing.

Next the Chinese team visited New Zealand, where delegates were able to meet with a range of people involved in postharvest operations, and to study postharvest facilities and equipment. Due to unavoidable delays, this took place in October 1998, after the results from the previous season in China had been completed. These data indicated that, while production was increasing as expected, returns to growers were falling as a result of oversupply to the market at the peak harvest times. This highlighted the challenges faced by growers, and the need for better domestic and international marketing options. Extensive discussions took place about the nature of the workshop. It was agreed that the workshop would be run with the purpose of introducing the concept of total quality management to growers and support personnel who would be involved in the development of a pilot program based on the Yun Cheng City region.

Workshop in China

In the final phase of the project, the New Zealand team visited Yun Cheng City and presented a five-day workshop to selected representatives of local growers and support industries. Names of delegates were advised to the New Zealand team approximately three weeks before the workshop. In this way the New Zealand team was able to ensure that a reasonable representation of women, growers, and support personnel were included in the list of delegates. In the end, a total

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of 37 people attended the workshop, although most of the time there were 28 persons present including 10 women. The majority of those attending the conference full-time were growers. Support personnel attended various sessions, particularly the sessions at the later stage of the workshop where the critical issues of management, structure and policy were discussed. A variety of training techniques was employed, recognising the nature of the participants. Most of the delegates attended every session for the entire workshop.

In preparation for the workshop, the New Zealand team prepared a workshop manual (Studman and Opara 1999). The key parts of this manual were translated into Chinese. Information received from companies was compiled into an appendix. The manual was given to all delegates at the workshop. As part of the workshop manual, a draft outline of a code of practice was prepared.

At the start of the workshop, growers indicated some concern about the nature of the workshop. It was evident that they required as much technical information from us as possible about ways to improve what they were doing in the orchard. It became evident that if this view predominated, then the growers amongst the delegates would be unlikely to shift their attitudes towards a more market and customer-orientated view of quality. For the first day and a half of the conference the prevailing attitude was that there was too much information being given about postharvest technology, whereas the majority of people present were growers who were really only interested in improving what they did in the orchard. The critical phase of the workshop was reached when we used the 'leaky barrel' model to describe a total quality management system. During this phase, we asked the growers, using a show of hands (5 = excellent to 1 = poor) to indicate their views on the state of various parts of the system for growing, handling, storage and marketing of their fruit. When we asked them to say how good each system was, growers indicated that, on the whole, what they were doing in the orchard was of a reasonably high quality. However, they realised immediately that the postharvest components were lacking. When this was presented to them in the form of the 'leaky barrel' (Figure 1), the message appeared to go home. Subsequently, we were advised by two or three observers that this model had been highly effective in convincing the growers of the need to improve the postharvest component of the system. The leaky barrel was subsequently left displayed in a prominent position for the remainder of the workshop.

It became evident that an important aspect of the workshop was to bring growers on board with the concepts of a total quality management system, incorporating some form of marketing organisation which could handle the development of quality standards for the industry.

Before, during, and after the workshop, discussions took place between the New Zealand team and Shanxi Agricultural Development Bureau representatives. These discussions focused on the continuation of the program and the development of the initiatives started by the project. At the conclusion of the workshop, a summary of the findings and recommendations of the workshop was completed.

Evaluation of the Effectiveness of the Training and Technology Transfer

In order to evaluate the effectiveness of the workshop, delegates were asked to fill in a questionnaire at the beginning of the workshop. This questionnaire attempted to identify the delegates' understanding of quality and quality management systems. At the end of the workshop, the delegates were asked to fill in the same questionnaire again.

In addition, on the first day, delegates were asked to vote on the best definition of the term 'quality'. At the end of the workshop, delegates were asked to vote again. Each delegate was given 10 yellow stickers and invited to place them against a series of suggested definitions of 'quality' which had been provided by suggestions from the delegates and by the workshop organisers. Finally, at the end of the workshop, delegates were asked to indicate how successfully they believed the workshop had met the objectives specified. This was achieved by asking delegates to raise one hand with the number of digits indicating their views. Thus the scale used was 5 = excellent; 4 = good; 3 = reasonable; 2 = not so good; 1 = poor.

Delegates were clearly satisfied at the end of the workshop that the objectives had been achieved (Table 3). For all objectives we obtained a score of around 4 (indicating that we had met the objective well). In addition, in the written survey, almost all delegates indicated that they had learned more about the subjects listed, or now understood the subject well.

From the assessment, it was clear that growers had moved from a view that value for money would be an acceptable definition of quality to a more customer-orientated view. This was the clear aim of the workshop, indicating that we had achieved our

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objective in increasing the delegates' understanding of total quality management systems.

Pre-workshop and post-workshop questionnaires

The results of the pre- and post-workshop questionnaires showed that we achieved a significant shift of opinion about quality and about the key terms involved in the development of quality marketing systems. In all, 26 pre-workshop questionnaires were received. These were coded with stickers so that we could pair the initial survey with the final survey for each person.

Initially, over half the delegates felt that they understood the terms 'maturity', 'ripeness' and 'spray diary' very well. Areas where they felt a need to improve their understanding were with regard to 'quality standards', 'code of practice' and 'quality control'. To a lesser extent, 'total quality management', 'quality assessment methods' and 'food safety' were also areas of interest, although delegates had some awareness in these areas. At the end of the course almost all delegates responded that they now understood these topics very well, or that they understood them better.

Before the workshop, when asked "Our apples will be best if…" (followed by a list of options), growers identified production features (producing fruit well, using best varieties and using better technology). Twice as many growers indicated that using more chemicals would result in better apples than using fewer. At the end of the workshop delegates ticked many more boxes, indicating that they felt that a multiple answer was more appropriate. The numbers of respondents indicating 'more' and 'less' chemicals was about equal. The highest rated factor was the need for a better quality control system. Almost all delegates marked this choice compared to under half at the beginning of the workshop. Similarly the number of individuals who responded that "the people buying the apples think they are better" was a key factor also doubled.

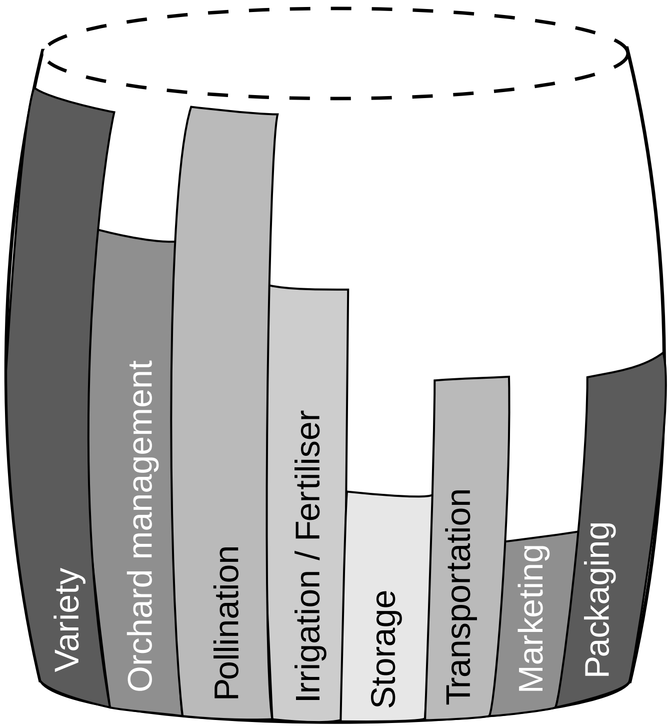

Figure 1. The quality barrel: how much quality will the barrel hold?

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Table 3. Assessment of how well workshop aims were met, where: 5 = excellent, 4 = good, 3 = reasonable, 2 = not so good, 1 = poor (average estimated by two observers).

Objective	Score
To provide information about pre and postharvest equipment and systems used in New Zealand.	4
To provide a basis for a plan for the development of the project	3.75
To develop the outline for a code of practice for a quality assurance system	4
To improve delegates understanding of quality, and total quality management (TQM)	4.75
To identify steps required to set up a TQM system in the County	4.25
To answer the following requests for information:	
New types of agro-chemicals, application methods and regulatory standards	4
Quality standards—what are they?	4.25
Equipment and measurement techniques for fruit quality	4
Implementation of a quality assurance system—people involved and their tasks (i.e. organisational framework required)	4
The role of research and development (R&D)	4
New production and postharvest techniques to assist in meeting export standards	4
Pre-cooling and extending storage and shelf life	4.25
Food safety—criteria and measurement	4.25
Overview of the New Zealand fruit industry—marketing	3.75

When asked "Where is the best place to start improving the *quality* of our apples?", a similar response occurred. Initially delegates identified orchard characteristics and activities as being the area in which to improve quality. After the workshop they identified quality control systems, teaching and training, better cool-stores, and a quality research laboratory, higher than the in-orchard features. Again, many more choices were ticked after the workshop than before.

In response to the question "Where is the best place to start to improve the *income* from apples?", delegates before and after the workshop identified the quality control system as the best place to start. However, afterwards teaching and training were also highly rated. Other aspects of a quality system were also identified by more delegates.

In response to questions on specific subjects, it appeared that more delegates were aware after the workshop that marketing was used. However the shift appears to have been from those who felt that it was already working well to those who felt it could be done better. In response to the questions on quality control, cool chain management, spray diary, controlled atmosphere storage, and food safety, there was a shift to the view that these were in use but could be done better. The change came from delegates who previously had indicated that they did not know what these terms were.

Summary

These questionnaire responses showed that, after the workshop, the attitude of many of the delegates had shifted to the view that it would be possible to do key postharvest operations better. Delegates also indicated that they were better informed, and were concerned that the current system was not working effectively.

Implementation of a Total Quality Management System

On the last full day of the workshop, a considerable amount of time was devoted to discussion groups among the delegates to identify what would be needed for the introduction of a quality management system for apples in Yun Cheng. Delegates were put into groups of five or six and asked to discuss the question "Could we develop a total quality management (TQM) system in Yun Cheng?" They were also asked to consider how close they were to a system and what would be needed to implement a TQM system. Each group was asked to look at one aspect of the TQM system.

The responses indicated that the delegates had taken on board the ideas and concepts developed in the

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workshop. Given the predominance of growers rather than administrative and support personnel, this represented a clear shift of opinion and also indicated an interest and a willingness to adopt the ideas which the Shanxi Agricultural Development Bureau were anxious to achieve. We subsequently learned that the growers had decided to initiate the formation of the Growers' Association, and had arranged the first meeting to take place just 10 days after the workshop. Given that this initiative came from the growers, rather than the Development Bureau, this indicated the extent to which we had achieved a shift in attitude of growers.

At the completion of the workshop, the Chinese team asked us to give our recommendations and views on the implementation of the decisions made at the workshop to establish a cool-store facility and a growers' association in Yun Cheng. These recommendations were conveyed verbally to the Chinese team, and presented in the final report (Studman 1999).

The issues covered were: who will be involved in the grower' association, decisions on the cool-storage system, the quality management system, publicity, marketing, grower association structure, the development of the quality assurance manual, development of appropriate infrastructure facilities, further technical inputs and funding for additional projects, and the future involvement of consultants.

Gender Issues

In accordance with the sponsor's requirements, our insistence on a minimum of 10 female delegates at the workshop ensured the issue of gender balance was addressed by the Chinese farmers. Although women were in a minority in all areas, nevertheless there were women filling a number of key roles in the infrastructure. In particular, at the district level, one of the key coordinators was involved in the strategic discussions with the Shanxi Agricultural Development Bureau was female. Amongst the growers' representatives, three or four of the women exercised significant leadership roles in the groups. Since delegates attending the workshop will now have a significant role in the formation of the Yun Cheng Growers' Association, we believe the workshop has facilitated and empowered women in leadership roles. It was noted that the initiative for establishing the first meeting of the Growers' Association came from one of the women delegates.

Discussion

The introduction of total quality management systems to any industry or organisation carries with it some implied basics. One of the key features is the commitment to participation of everyone involved in the organisation. This appears to be particularly fitting for the Chinese system where collective decision-making is a possibility. A further key feature is that quality improvement arises by identifying the current position and attempting an improvement from that position. Therefore the workshop has been effective in committing the delegates to identify improvements which are appropriate to the level of technology which they have already reached.

The initial visit made by the New Zealand team convinced us that implementation of technology from overseas was achievable in the environment within certain limitations. The major difficulty we identified was a narrow focus on quality, largely based on the idea that fruit produced to the top quality in the orchard will therefore be top quality fruit to the customer. Unfortunately this is not the case, since postharvest factors can completely alter the situation. By identifying the need for a systems approach to the problem, the workshop achieved the aim of identifying weaknesses with the current system and seeking to identify ways to move forward from this. The decision to proceed with the program to develop a pilot plant focused around the development of postharvest handling and storage facilities by the Chinese indicates the success of our training.

Inherent in the total quality management approach to the postharvest system for fruit is the recognition that the introduction of technology carries with it the need for equipment maintenance and support. Since the cool-store facility is likely to be developed using Chinese funds and resources, it is evident that ongoing costs are more likely to be funded from local resources.

In our view this project has indeed been an outstanding success. Taken as a whole, our initiative in providing technical input to run the workshop and provide external assistance to the fruit growers in Shanxi Province has resulted directly in the decision to apply for a two million yuan grant to enable the development of cool-store facilities. This in itself will bring about a significant improvement in the quality of postharvest systems in the county. The pilot program will also act as a project capable of wider application when demonstrated to be successful.

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Our workshop has also been instrumental in convincing growers of the need for a growers' association in Yun Cheng. This organisation has the potential to be a marketing body for the growers, thereby ensuring a united front in marketing their produce. The importance of apples and other fruits as a developmental tool in the region is readily apparent from discussions and observations in the area. Significant redevelopment is taking place, and extensive rebuilding and prosperity has come to the region. The return from apples has been extremely good, giving growers a three or four-fold increase in profits per unit area of land. While the fall in price for fresh fruit in October/November 1998 has dampened the enthusiasm somewhat, our workshop and the suggestions for ways of increasing the return through good postharvest handling systems has given the delegates some refreshed enthusiasm for fruit growing.

It was evident from the emphasis on a final signing ceremony, and the importance attributed to written findings from the workshop which indicated the potential for external technical assistance, that the value of our input could not be underestimated. It is evident that the Chinese side is extremely dependent on continued inputs of technological assistance from outside China. Our willingness to be involved in the long-term in this project was paramount to the success of the program.

Conclusions and Recommendations

- The project met and exceeded its aims.
- The workshop and our involvement with the Shanxi Agricultural Development Bureau have resulted in the Chinese counterparts wishing to commit significant in-country funds to the project's development base.
- We have provided a framework for the introduction of a total quality management system amongst growers in Yun Cheng City. This system has given leads and guidelines for the introduction of technical, institutional and developmental improvements.
- Gender issues have been addressed successfully in this project.
- The involvement of the Shanxi Agricultural Development Bureau, the China Agricultural University, and Massey University has resulted in an increased understanding between these three groups. We believe we have laid the foundation for a continued interaction and collaboration for a long-term program of technical assistance in the development of postharvest systems in Shanxi Province.

The main recommendations were as follows:

- Formation of a growers' association to focus on developing a quality management system for apples (already actioned). Establishment of a marketing effort was identified as a key task of the association.
- Development of additional cool-storage facilities (Chinese proposal supported and submitted).
- Further proposal to extend the project, with the continued involvement of the New Zealand team in assisting with the development of facilities, postharvest systems and the quality management program.
- There is a need for research, testing, and advisory systems to be established to enable growers to make continuous improvements to their pre and postharvest systems.
- Further international technical assistance is still required, both in the short and long term.
- The workshop was most successful and could be repeated with other groups in China and elsewhere.

Acknowledgments

We would like to thank Professor Gao Huanwen (China Agricultural University), Mr Li Ren An (Director of the Shanxi Provincial Agricultural Comprehensive Development Board), and Professor Gavin Wall (Massey University) for their assistance in formulating the proposal and enabling this project to proceed.

We would also like to thank the New Zealand Ministry of Foreign Affairs and Trade for their support, through the Asia Development Aid Foundation.

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New Market-pull Factors Influencing Perceptions of Quality in Agribusiness Marketing (or Quality Assurance for Whom?)

L.U. Opara*

Abstract

The term 'quality' is elusive and connotes different meanings to different people. Quality is also dynamic and reflects both time and position in the entire food supply chain. The producer, handler/marketer, consumer, and other stakeholders have both influences and perceptions on product quality. There is also a product-oriented definition of quality. In many developing countries, it is a commonly held view that importers from developed countries usually wanted it all their own way by defining both the quality required and the price to be paid. In this paper, we will review the different orientations of quality, including the emerging influences of sustainability of production systems and genetic modification, and the implications on export marketing of agricultural produce from developing countries.

INTERNATIONAL TRADE in fresh agricultural (and horticultural) food products has expanded tremendously during the past decade. This trend has been spurred on by changes in food consumption patterns, particularly in the developed economies in Europe and the United States of America (USA). Consumers are increasingly eating to express their personal values, concerns and aspirations. Consumers also want assurances on freshness, taste, safety/traceability, health/nutrition, animal welfare, sustainability/environment impacts, zero waste, and fair trade. These factors contribute to the overall perception of 'quality'. More than before, the quality of fresh agricultural produce has come under considerable scrutiny by consumers and the general public. Both producers and marketers face the challenge of balancing profitability with increasing customer demand for high quality products backed by a consistently reliable support service.

The increasing global demand for fresh fruits and vegetables creates opportunities for many developing countries, which produce a range of tropical and sub–tropical products. However, to participate competitively in the growing and marketing of fresh food products, appropriate quality assurance (QA) must be developed and implemented to meet customer expectations. This requires a good understanding of (a) the international trends and challenges in agribusiness marketing; (b) the various perceptions of 'quality' throughout the entire chain; and (c) the market-pull (demand/consumer) factors influencing these perceptions. The objective of this paper is to discuss these global trends and perceptions of quality in relation to the development of QA systems.

Globalisation and Current Trends in Fresh Food Consumption

Global trade in fresh fruits and vegetables has increased steadily during the past decade. Changing market trends and innovative industry management have characterised this era, and will continue to influence the way fresh commodities are supplied. Greater labour mobility and demographic shifts in major metropolitan areas have resulted in the introduction of new fresh food products and changing food patterns, particularly where new immigrants are higher consumers of fresh fruits and vegetables. This opens up further opportunities for international trade

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Quality assurance in agricultural produce,
edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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in both tropical, subtropical and temperate fruits and vegetables.

Several global trends in business will continue to impact on current and future global agribusiness marketing, including:

- increasing competition;
- legislative and regulatory demands;
- speed of economic change;
- rapidly changing information and communications technology; and
- global sourcing and strategic alliances.

Rapid growth in information and communications technology, and the unrelenting surge in the use of the Worldwide Web, have led a single, highly networked world, affecting the way we access data and technical information for production, handling and marketing of products. The General Agreement on Trade and Tariffs (GATT), formation of regional trading blocs, and increasing influence of the World Trade Organization (WTO) have facilitated the expansion of international trade in horticultural and agricultural products. The increase in global fresh commodity trading during the past decade is exemplified by the steady increase in the export and import of horticultural products in the USA, a trend that is forecast to continue (Tables 1 and 2). This trend is also matched by an increase in fresh fruit and vegetable consumption for the past three decades, rising from 257 kg per person in 1970 to 307 kg per person in 1993 (Anon. 1996).

The rise in fresh fruit and vegetable consumption (ranked #7) is one of the top 10 'mega-trends' in food consumption patterns (Sloan 1996). Particularly critical also is the popularity of 'fresh' as the most desirable food label (ranked #5). The quality and variety of (i) fresh fruits and vegetables and (ii) fresh meat ranked second and third, respectively, right behind a clean store, as the reasons consumers elect to shop in a grocery store. This study further noted that the emerging trend for organic foods was yet to reach its full potential (Sloan 1996). Increasingly, consumers are eating to express their personal values, concerns and aspirations. Consumers also want assurances on freshness, taste, safety/traceability, health/nutrition, animal welfare, sustainability/environment, zero waste, and fair trade. These trends in food consumption patterns, coupled with the overwhelming desire for convenience, provide a powerful driving force behind food production and international agribusiness marketing.

Table 1. Exports of fruits and vegetables from the United States of America (US$1,000). (Source: Brown 1996.)

Year	Fresh fruits	Fresh vegetables	Processed fruits and vegetables
1989	356 015	1 134 657	1 000 616
1990	728 648	1 486 489	1 246 753
1991	832 935	1 561 053	1 394 490
1992	899 624	1 683 344	1 558 121
1993	985 953	1 707 147	1 639 583
1994	1 046 789	1 953 767	1 720 891
1995	1 068 572	1 972 864	1 906 561

Table 2. Imports of fresh and processed fruits and vegetables into the United States of America (US$ million). (Source: Brown 1996.)

Year	Fresh and processed fruit	Fresh and processed vegetables
1989	1 820	2 047
1990	2 219	2 266
1991	2 131	2 214
1992	2 216	2 184
1993	2 037	2 450

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Strategic Trends in Agribusiness Marketing and Impacts on Quality Management

Agriculture (and horticulture) is a dynamic industry. Over the past century, we have witnessed the evolution from production-focused agriculture (basic family food supply) to market-oriented agribusiness. Agriculture (including farming) is radically changing to fewer, larger, more sophisticated firms with growing global influence. Competition is shifting to exclusive, shorter, higher technology, higher integrity supply chains, with increasing power of supermarket chains. For instance, global corporations such as Dole, Del Monte, and Chiquita dealing with fresh foods, as well as highly successful marketing cooperatives (such as ENZAFRUIT and ZESPRI in New Zealand), are increasingly expanding their global network so as to increase their market share and provide year-round supply of commodities.

These firms are increasingly applying the concept of 'supply chain management' to the production and delivery of products and services worldwide (Lummus and Vokurda 1999). Global interest in supply chain management has increased steadily since the 1980s as a result of the realisation that collaborative relationships within companies and beyond their own organisations was beneficial. This concept involves managing supply and demand, sourcing raw materials and/or products, manufacturing and assembly, warehousing and inventory tracking, order entry and order management, distribution across all channels, delivery to the customer, and the information systems necessary to monitor all these activities. Supply chain management coordinates and integrates all these activities into a seamless process to ensure that the following conditions are met in the production and handling of agricultural produce:

- use of uncontaminated raw materials;
- clean growing and harvesting conditions;
- specification of product attributes;
- cool-chain control and maintenance;
- commitment to regulatory protocols;
- evidence of an agreed quality assurance (QA) system; and
- use of Good Agricultural Practice (GAP) and application of internationally recognised quality food safety programs such as Hazard Analysis and Critical Control Points (HACCP).

What is Quality?

The use of superior product quality as a competitive weapon is widely recognised and documented (Garvin 1984). Although the quality of both product and service is widely recognised as important for successful agribusiness, there is often a lack of understanding or agreement on the meaning. This has resulted in a plethora of definitions of quality, often reflecting the type of product, stage in the postharvest handling chain, or the intended use (Botta 1995; Abbott 1999; Shewfelt 1999; Bremner 2000).

Quality is a concept and is dynamic; and thus there is no single, brief, consistent, and universally accepted definition. Shewfelt (1999) argued that the primary dividing line between differing concepts of quality is orientation. Producers, researchers and handlers are mostly product-oriented, in that quality is described by specific attributes of the produce (such as firmness or colour), while consumers, marketers and economists are more likely to be consumer-oriented in that quality is described by consumer wants and needs. Plausible as these viewpoints may sound, particularly in relation to commercial needs, Abbott (1999) argued that it is difficult to divorce the two viewpoints and viewed quality in terms of instrumental or sensory measurements of product attributes that combine to provide an estimate of customer acceptability.

With respect to agricultural and horticultural products, quality involves all of the attributes, characteristics, and features of a product that the buyer, purchaser, consumer, or user expects. A product with excellent quality clearly meets the buyer's or user's highest expectations. Kruithof and Ryall (1994) provide a succinct and definition of quality applicable to agribusiness: "Quality is consistently meeting the *continuously* negotiated expectations of the customer and other stakeholders in a way that represents value for all involved". In practical terms, the customer wants the right product, at the right time, at the right price, and with the right support! The quality of an agricultural/horticultural product is assessed from the relative values of several characteristics which, considered together, will determine the acceptability of the product to the buyer and ultimately the consumer

Developing a good understanding of quality concepts is necessary before strategic marketing issues can be adequately addressed. The orientation of quality adopted will undoubtedly influence the quality standards (product specifications) and techniques used to assess quality. It could also create barriers to quality improvement (Shewfelt 1999). In this respect, the

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edited by G.I. Johnson, Le Van To, Nguyen Duy Duc and M.C. Webb.
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dynamic nature and non-specificity of quality must be kept in mind.

Dimensions of Quality

Recognition of the fact that quality is not a single, recognisable characteristic poses a considerable challenge for organisations. Garvin (1984) argues that what is needed is a synthesis of the various definitions and approaches to quality, based upon a careful separation of the various elements of quality. The author suggested the eight dimensions of quality defined in Table 3, stressing that each dimension is self-contained and distinct, for a product can be ranked high in one dimension while being low in another.

Each dimension of quality imposes different demands on the business, and the implication is that the companies should carefully define the dimensions of quality in which they hope to compete, and should then focus their human and capital resources on these elements. Using examples from the automobile and other manufacturing industries, Garvin (1984) showed that a firm is likely to be more successful in pursuing a strategy of high product quality if it selects a small number of dimensions in which to compete, and then tailor them closely to the needs of its chosen market. These principles are equally applicable to agribusiness marketing.

O'Mahony et al. (1994) outlined other general points about 'quality' based on the literature which may be readily applicable to the agricultural and horticultural industry:

- consumers respond to differences in product quality and service; and
- producing higher quality product reduces rather than increases production costs in that labour is able to concentrate more consistently on higher standards.

With respect to profits, Farris and Reibstein (1979) showed that marketers who inform consumers about quality differences in their product attract higher prices than those who depend on high quality to communicate itself to consumers.

What is Quality Assurance?

Modern agricultural/horticultural producers and exporters recognise that quality is the most important factor for success in the international free trade, and the main difference between very demanding consumers and others is their insistence on quality product and service (Patnaik 1996). As consumers demand and expect higher and consistent quality/safe fresh food products, growers, handlers and others in the marketing chain must respond to maintain their market share. This requires the development and implementation of quality management systems to reduce variability and maintain quality at all steps in the postharvest chain. These management systems enable to grower to respond to the ever-changing and often conflicting demands of consumers, who are increasingly demanding greater consistency in supply and quality, as well as safety and traceability.

Traditional quality management practices involving product inspection (for finding and removing defects) and quality control systems (for reducing defects) are no longer sufficient to meet the consumer requirements. A fundamental principle underpinning modern approaches to quality management is the need to manage the process, not the output. Consumers paying a premium for quality need the assurance that the product specifications and other criteria have been met. Many global suppliers of fresh produce

Table 3. Dimensions of product quality. (Adapted from Garvin 1984.)

Dimension	Explanation	Possible application to fresh fruits and vegetables
Performance	Primary product characteristics	Firmness, colour, sugar
Features	'Bells and whistles'	Packaging, labelling
Reliability	Frequency of failure	Both in supply and product characteristics
Conformance	Match with specifications	Variability
Durability	Product life	Storage and shelf life
Serviceability	Speed of repair	Speed of recall or replacement
Aesthetics	'Fits and finishes'	Presentation, display
Perceived quality	Reputation and intangibles	Quality assurance system

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acknowledge food safety guarantees as the single biggest issue for consumers (Marks 1999). As a result, retailers want not only documentation of every aspect of growing and delivery regimes, but also want demonstrated and audited efficacy of labour practices, energy conservation or community contributions (Marks 1999). In addition to the consumer, there are other influential stakeholders who have shown interest in the way we grow and market agricultural products. In a recent article on securing market access, Chandler (1999) argues that it is no longer the customer that needs to be sold, but rather the government, consumer groups and public perception itself.

Quality assurance (QA), therefore, involves those planned activities designed to consistently satisfy customer expectations by defining objectives, planning activities, and controlling variability. Leamon (1989) defined QA as all those planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy stated or implied needs. Obviously, this requires the systematic interaction of products, services, processes and people. An effective QA system ensures that the quality of the inputs (resources, staff, aims and intended outcomes) and the quality of the process (grading, handling and marketing) are well planned and managed. The intended output quality (product specifications) must be agreed upon from the outset and not imposed or manipulated at the end of the chain. Ultimately, the success of any QA scheme is dependent on the integrity of the auditors who conduct the QA assessment or verification (Lewis-Jones 1998).

Several factors have been identified as important in the development process for QA in horticulture (Leamon 1989):

- definition of quality specifications for the product;
- development of quality control procedures and recording system;
- documentation of the first two points with photographic interpretation in a product quality manual and training material;
- documentation of 'typical' process flow charts and hazard analysis—these are incorporated in a 'model QA manual' which can be used as an example for people unfamiliar with QA; and
- development of training programs for people involved in controlling quality, e.g. pickers, packers and quality controllers.

Legge (1998) discussed four preconditions for successful QA, namely:

- clearly set objectives which are part of the corporate philosophy, ensuring that QA staff cannot agree to short-term expedients which may damage long-term growth;
- a strategic plan incorporated into commercial objectives;
- use of all available tools; and
- an adequate number of suitably trained staff.

It was considered that the most important factor of all these is that QA staff must be an integral part of a buying/selling team.

Implementing a QA program brings several obvious benefits to the grower, marketer, consumer, and other stakeholders including (LRQA 1999):

- better management control;
- improved producer – supplier – consumer relationships;
- less waste and lower costs;
- greater staff motivation and reduced staff turnover; and
- improved customer satisfaction.

QA plays an important role in the maintenance of quality at all levels and tolerances acceptable to the consumer. With respect to international agribusiness marketing, QA and quality standards play a crucial role in creating confidence and ensuring the delivery of consistent quality and safe products. It must therefore be considered as a science and not an art. It is not based on individual personal judgement, but on statistically treated physical, chemical, microbiological and sensory measurements (Askar and Treptow 1993). QA considerations and procedures must be applied at all stages in agricultural production, including procurement of planting materials and extending to all steps in the postharvest chain, with the main emphasis on creating the conditions that lead to the satisfaction of consumer needs and want. QA acknowledges that fixing a quality defect after it has occurred is either very difficult or very costly (Andrews 1999).

Quality Assurance for Whom?

The production and handling of fresh fruits and vegetables is an integral part of the global food manufacturing industry. Unlike other manufacturing industries, such as automobile and electronics, the agricultural and horticultural industry is characterised by huge variations in growing conditions, which also contribute to considerable variation in product quality. Improper control of the numerous postharvest conditions (such environmental temperature, relative

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humidity and packaging) and differences in staff performance at each stage in the chain create additional variations which exacerbate the quality variability problem. Therefore, the importance of QA covering all aspects of the production and distribution chain cannot be overemphasised. However, given the various orientations and dimensions of quality discussed above, and the considerable influence of many stakeholders (Chandler 1999), one could ask the question: QA for whom?

Earlier in this paper, I highlighted some trends affecting agribusiness and consumption patterns. Globalisation, changing technology and the increasing impact on the production and marketing of products, increased international competition, international trade agreements, and the increasing consumer demand for consistent high quality products are some of factors forcing growers to re-examine the way they do business. Put together, these factors create push–pull factors that influence the perception of quality as well as the strategy for agribusiness marketing. To meet the challenges posed by these global trends and remain profitable, we are now witnessing a paradigm shift from technology-push (oriented towards the product, output/yield, producer, supply-driven) to market-pull (consumer, attitudes, demand-driven) in agribusiness.

Market-pull Factors Influencing Perceptions of Quality

The successful fresh food supply chain will become an increasingly complex web, resulting in mutual relationships between the producer, marketer and consumer to meet new consumer demands. The new market-pull factors (new demands) include (Hughes 1994; Hofstede et al. 1998):

- high quality and safe products;
- environmental and ecological sustainability considerations in production and distribution;
- animal welfare considerations;
- products in broad assortments available year-round;
- short lead times (fresh products!); and
- competitive prices.

These factors have resulted in increasing product differentiation and customisation to satisfy consumer demands for health/nutrition, safety, organics/naturalness, labelling, ecological/environmental responsibility, social responsibility, and a peace of mind! Let me comment briefly further on safety and organics, two factors which have become increasingly influential quality factors in fresh food marketing.

Food safety

Unfortunately, fresh food products such as eggs, beef, chicken, milk, pork, fruit and vegetables have one thing in common: pathogens. This is exacerbated by some agricultural practices (such as spreading animal slurries and human faeces as manure) and poor sanitation and inappropriate postharvest handling practices. Recent fresh food poisoning incidents around the world have resulted in crises of confidence in the food supply chain. Food safety has come under the spotlight and is now the single biggest issue for consumers. Fresh fruits and vegetables, meat, eggs and chicken have been implicated with pathogens, which pose health risks to humans. *Campylobacter* in chickens, *Mycobacterium paratuberculosis* in milk, *Salmonella* in poultry and eggs, and the link between bovine spongiform encephalopathy (BSE) in cattle and new variants of Cruetzfeldt Jacob disease (CJD) in humans are some of the potential safety hazards in our food chain.

Although the incidence of food-related illnesses from direct consumption of raw fruits and vegetables is low, the risks are real. The potential for high pesticide residue levels on produce and the discovery of newly emerging pathogens present further problems for the fresh food industries (Andrews 1999). Many countries have passed new, stringent food safety laws, and set up new food safety agencies to develop policy and implement strategies to ensure public confidence in the food chain. In addition to reducing the incidence of food-related illnesses and death, these actions will also reduce the costs to the public health system and increase labour productivity.

Despite the above actions of some governments around the world, many consumers have generally lost confidence in the ability of governments to protect public health and of science to understand the nature of some of the food problems (McKechnie 1997). This focuses attention on producers, the fresh food industry and retailers. As consumers demand action and answers, there is no indication that this pressure will reduce in the near future especially as the debate over genetically modified foods continues (Halford 1999). Increasing transparency, traceability and assurance have become the norm in modern agribusiness enterprises.

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Organics—a new quality attribute

Increasing public interest in environmental sustainability and our changing lifestyles have raised concern about current farming practices and raw material inputs. These interests have been championed by very powerful political and social interest groups such as the Green Party in New Zealand, Greenpeace, and the Society for the Prevention of Cruelty to Animals (SPCA). The increasing awareness and support of these environmental and animal welfare philosophies has created a new demand for 'organic' food products. For some consumers, 'organic' equates with 'farm fresh', and represents a critical quality attribute. The increasing demand for organic products and the premium prices they command in the marketplace are very significant trends that cannot be ignored by growers and marketers of fresh foods.

To illustrate this growing influence of organic fresh foods in the global agribusiness, let us consider the data from the USA showing dramatic sales increases in recent times. Currently, organic foods account for less than 1% of all food sales, with over 20% annual growth over the past 6 years. It is projected that organic sales will double from \$3.7b in 1997 to \$7.2b in 2000 (Stauffer 1999). A recent survey showed that 60% of all Americans are either consumers of organic foods or interested in these products (Sloan 1998). Increasing concerns about food safety, wholesomeness and genetic modification are converting erstwhile cynics into believers in organic fruits, vegetables and meat products.

The 'organic wave' has also been noticeable in many other parts of the world, including New Zealand. Newspaper headlines such as "Farmers urged to ride Europe's organic meat wave", "Organic apples growers' hope", and "Organic apples sweet" are typical. Over the past three years, organic apples represented 1.5% of the 15.5 million apple cartons exported through ENZAFRUIT International, with 30 of New Zealand's 1,600 export apple growers making the switch to organic. Premium returns up to 30% over conventional fruit were recorded over the same period (Sheeran 1999). One Hawke's Bay organic apple grower earned a gross return of NZ\$109,231.00 per ha, earning NZ\$39.88 per carton compared with growing conventional apples which would have earned him NZ\$39,000.00 per ha, at NZ\$14.10 per carton. Organic meat could demand a premium of 20-40% (lamb), 100% (beef), 200% (pork) and 300% (chicken), reflecting the difficulties in producing these animals organically (Anon. 1999). The three years of transition from conventional farming to gain organic certification represents loss in production over that time, and growers need to be aware of this.

Implications of QA for Least Developed Countries

Many developing countries cannot participate in the growing international and regional trade in fresh produce due to a lack of appropriate postharvest techniques, and inadequate infrastructure and marketing systems. Numerous smallholder farms, often less than 2–3 ha and scattered in many locations, pose special problems in forecasting product supply and managing variability. Agriculture in these countries is still at subsistence level, with limited scope for market-oriented production. With stringent quality and phytosanitary requirements in an international market dominated by a few large companies and marketing cooperatives, small-scale farmers in developing countries face huge difficulties to compete favourably.

Most developing countries suffer trade deficits on fruits and vegetables (Hutabarat 1989). However, there is a large number of crops in these countries which bear edible fleshy parts or nuts of acceptable quality and which have considerable economic potential as international commodities (Menini 1991; Wood and Payne 1991). As the production and marketing of the traditional tropical and subtropical fruit crops come under pressure due to increasing supply and over-supply and declining profits in some regions or seasons, there is a need to develop suitable postharvest technologies and quality management systems for the production and marketing of these lesser known crops which have food potential. Improving quality control and implementing QA systems will enable these developing countries to derive benefits from these crops by trading competitively in the lucrative global trade in fresh commodities. The domestic market could also benefit from the improvements to quality standards and development of QA systems.

Certain socio-cultural factors must be considered in developing quality management systems in these developing countries. For instance, horticultural production and marketing follow a clearly-defined gender line in many places, with women predominantly engaged in vegetable production and marketing, while the men are active in fruit production. Religious beliefs and cultural taboos cannot be ignored as these may impact on the adoption and continued use of

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appropriate postharvest technology and the successful implementation of QA techniques.

Where export marketing is pursued, growers must participate in setting the quality standards, and receive financial incentives (higher price) to raise quality. Personal experience of the author in the development of horticultural export marketing in Mali under a World Bank Project, showed that many small-scale farmers feel powerless and believe that importers want it all their way by setting quality standards as well as the product price. Efforts to assist these countries must equip them with the tools of QA and the marketing skills to derive the benefits of improvements in product quality.

Conclusions

Globalisation, competition in international trade in fresh food commodities, changing food consumption patterns, and increasing consumer-orientation of quality are challenging the traditional perceptions of quality. These create strong market-pull influences such as food safety, organics and personal attitudes as important new quality factors in agribusiness marketing. QA systems are necessary to demonstrate transparency, traceability and assure quality of the product and other consumer expectations. These new market-pull factors pose considerable challenges for developing countries which have limited postharvest infrastructure and inadequate QA systems. In order to meet existing international quality standards so as to participate favourably in the competitive international trade in fresh commodities, postharvest technology transfer to developing countries must include the skills to develop and implement appropriate QA systems.

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