CHAPTER THREE

The Journey to You

Horticultural products are living things. Immediately after harvest, senescence is underway in plant tissue that starts to break down and begins to deteriorate. The journey of horticultural products from where they are grown to where they are used is a struggle against this natural process.

This deterioration occurs faster at warm than at cool temperatures. The most effective way to prolong shelf life is to remove the product from direct sunlight after harvest and then reduce to optimal storage temperature as soon as possible after harvest.

Most crops grown in temperate parts of the world can be kept at 0-1°C while those grown in tropical or subtropical zones can be stored at 10-12°C. Product quality is best maintained in refrigerated cool stores where temperatures are monitored and controlled accurately by computers.

Harvested horticultural crops are very perishable and can be damaged if handled in a rough manner during harvesting, sorting or transporting. Products damaged physically by pests or diseases deteriorate faster than non-damaged products and thus have a much shorter shelf life. Gentle handling and good packaging will reduce such damage.

A wide range of packaging is used in preparing and sending crops to market. Packaging serves three major functions: to preserve, protect and promote.

Preserve by extending shelf life. Protect by preventing physical and disease damage during handling and transport. Promote by having labels, brands, logos, country of origin, details of variety, weight, size and grower number printed and displayed on the package. In the current environment where sustainability is important, most packaging for export is recyclable, hence use of technologically advanced cardboard products and the increasing use of biodegradable films.

Postharvest life of some fruit and vegetables can be further extended by changing the atmosphere around the product, either in a sealed gas-tight cool store or in a polymeric film package that is differentially permeable to gases. The normal atmosphere of 79% nitrogen [N], 20% oxygen [O_2] and 0.04% carbon dioxide [CO_2] plus some other inert gases is changed to 1-5% [O_2], 1-10% [CO_2] with the remainder N. This reduced O_2 environment (controlled [CA] or modified atmosphere [MA] storage) slows metabolism, reduces ethylene production and action, delays deterioration and hence extends shelf life, especially for apples, pears, avocado, kiwifruit, mangos, plums, cabbages, sweet onions and broccoli.

Ethylene is a simple naturally occurring ripening gas produced by many fruit, vegetables and flowers. It has both positive and negative effects. It is necessary for normal ripening to occur but it can cause premature ripening, induce senescence and reduce shelf life.


Packaging methods can be very sophisticated for fresh export products or very simple for local market sales. (Left) sugar peas, Nairobi; (right) produce market, Seoul, South Korea.

Preparation for sale and display is meticulous and highly technical to ensure product safety and retention of quality. (Left) apples, New Zealand and (right) grapes, South Korea.

Commercially ethylene is used for ripening tomatoes, avocados, kiwifruit and bananas.

Low temperature and CA storage cause a reduction in naturally occurring ethylene production and action, and so delay ripening and deterioration.

What consumers desire most in horticultural products is freshness. But maintaining quality from farm to plate is only one of the many challenges facing those who manage the dynamic horticultural industry.

Like all customers in the modern world, consumers of horticultural products need and demand consistent quality, appearance, good presentation, taste, nutrition, health benefits and strict conformance with health and safety standards.

And just when horticulturalists meet these high standards there is the possibility they will all change. Consumers change their tastes and wants. New trends towards vegetables such as capsicums, broccoli and the convenience of bananas come along.

Consumers expect a year-round supply of many fruit and vegetables such as bananas, tomatoes, lettuces, apples, and oranges. Products are sourced globally to satisfy this consumer need, so effective, efficient supply chains are essential. Many consumers now recognise that most fruit and vegetables have health conferring attributes as a result of the '5 + a DAY' programme*.

Growers have to be able to respond quickly to market opportunities. Information on what is wanted and where it is required has to be transmitted back along the value chain to the growers.

Mastering the intricacies of marketing and positioning the product in retail selling points requires infrastructure and support services (such as refrigeration systems, cool store design, packaging, ICT inputs, transportation, reliable electricity supply, communication systems). To make sure all these tasks are completed well calls for the knowledge and expertise of scientists and technical experts.

*Please see page 56.

(Left) Packing avocado for export, Chile and (right), grading and packing asparagus, Thailand.

Fast, efficient, cost-effective preparation and sorting of produce is important to growers of horticultural crops. To obtain premium returns, it is vital that crops go to the best markets and that the highest quality produce can achieve the best price in the markets. Lesser quality can be profitably sold to consumers in lower grade markets or be directed to processing options such as freezing or canning. Good sorting enhances customer satisfaction, provides a higher average price for the crop and heightens the chances of return sales.

Consumers appraise fruit and vegetables by colour, size, firmness and sweetness and are not impressed with blemishes. Repeat purchases will occur if taste, juiciness and sweetness appeal to the consumer. The response of the horticultural industry to achieve product segregation for particular markets needs has been to design clever, innovative, highly sophisticated grading and sorting equipment.

Hi-speed accurate grading of fruit and vegetables

Fruit graders

Early fruit graders were adapted from other industries, such as egg graders that sorted fruit into categories according to approximate weight or size. Others followed a series of mechanical clockwork based devices, such as the Orbit grader designed by John Hancock in New Zealand in 1964, that literally lobbed fruit that according to weight fell into one of seven canvas chutes. That machine was used in the kiwifruit industry for a number of years but was replaced by modified machines from the apple industry.

The advent of the personal computer (costing $3,000 in 1980 and replacing the typically $50,000 main-frame machines of the time) allowed the affordable processing of algorithms in real-time, which meant that individual fruit could be assessed at blinding speed. Hence the evolution of the remarkable fruit and vegetable grading and sorting machines of today.

Clever high speed fruit graders

Modern equipment can now sort fruit by weighing and scanning individual units multiple times within milliseconds measuring weight, diameter, colour, shape, density, internal sugar content and blemishes. Using sophisticated technologies, including Near Infra Red (NIR) cameras, there is guaranteed accurate pack weights. Furthermore, the 20 to 30 images of each fruit that are captured can be used to produce an integrated image, recognise whether a small blemish is present or not (while recognising that both the stem and calyx are not blemishes) and sort the fruit by colour grade – all at the rate of 10 or more fruit per second, and then deliver each fruit to one of 50 predestined drop points on the packing line.

In California, USA, a single facility uses 40 such lanes to grade and sort Clementine oranges at a rate of 240 orchard bins per hour. This equates to 1.2 million pieces of fruit accurately sorted and graded per hour!

(Upper photo) In California a bank of high speed grading machines micro weigh and photo stitch analyse mandarins for blemishes across 40 lanes at 10 fruit per second per lane, and (lower photo) travel at high speed to assigned packing stations. PHOTO: WWW.COMPACSORT.COM

High speed grading and sorting of kiwifruit, New Zealand.
PHOTO: ZESPRI INTERNATIONAL LTD

Berryfruit graders

Small berryfruit, such as blueberries, have historically been sorted and packed by hand, with workers selecting out only 'good looking' fruit with above-average keeping qualities.

The advent of grading machines that could rapidly recognise different fruit qualities by colour was an innovation of huge benefit to high volume packers of berryfruit.

Soft berryfruits

A machine for sorting soft berryfruits had long been a dream for many fruit packers. The softness of fruit cannot be reliably detected by colour. It seemed that softness was a quality that could only be detected by the touch of a human hand and hand grading was slow and potentially damaging to fruit.

The solution was the development of a sensor technology which generated a sine wave from the contact that a berry makes as it falls from an angle onto a small sensor. There is a strong correlation between the shape of the sine wave that is generated and the softness of the fruit. Following detection, soft fruit are removed from the grading line by air jets.

Colour sensing technology

High speed berryfruit grader uses colour sensing technology to identify and air jets to remove non-conforming berries. PHOTO: WWW.BBCTECHNOLOGIES.COM

Colour sensing technology can be used to sort combinations of colours on individual fruit as small as 2 gm in weight. For example, it can sort blueberries at a rate of 100 kg per hour. A single 72 lane/1.2 metre wide machine can process 7,200 kg per hour.

Larger fruit (eg. 8 gm each) can be sorted at 200 kg per lane per hour – or over 14.4 tonnes per hour for the 72 lane model. These machines successfully process a wide variety of fruit and nuts, including: blueberries, cran-berries, olives, strawberries, cherries, cherry and grape tomatoes, peanuts, almonds and pistachios.

Individually wrapped and protected fruit in a supermarket, Beijing.

Beetroot: before and after washing in a high speed 'polisher'.

Washed and 'polished' potatoes exit this machine at the rate of 15 tonnes per hour. PHOTO: WWW.WYMASOLUTIONS.COM

Vegetable graders

Vegetables need to be cleaned, washed and graded for premium presentation – and in large quantities.

In the 1970s a company that was repairing farm implements and mechanical grading machines, started developing machinery for preparing fresh carrots, potatoes and parsnips and have now developed a 'Polisher' with a rotary barrel or drum and 14 brushes that rotate independently.

These machines, that can process 12 tonnes of carrots or 15 tonnes of potatoes per hour, have been installed in countries as far apart as Australia, Canada, Switzerland, Poland and Mexico.

Packaging

Effective packaging is paramount to horticultural products. It serves to protect the produce in transit, keeps it from contamination, reduces dehydration and if possible retains its freshness.

Sub-standard packaging not only presents the product poorly, but may also indicate to the customer that the product is of poor quality and even that it is unsafe. If a consequent purchase is not made then growers, suppliers, and indeed all the people in the supply chain, suffer financially and socially.

Plastic or moulded cardboard retail packs might seem simple items at first glance. However, such packages can in fact be a guard and defender of the contents. Good packaging can save waste, reduce shrivel through control of humidity, and be a physical barrier to pests and reduce bruising.

Well designed, effective packaging, therefore, gives the consumer a guarantee of freshness, vitality and safety.

If transport conditions and packaging are optimum, then the ageing of fruit and vegetables can be slowed down by as much as 800%.

An example of 'intelligent' packaging

Knowing when fruit is ripe and at its optimum state for eating is a vital matter to growers and to discerning customers. Fruit lovers like to enjoy fruit when it is 'just right' and may hesitate over buying excellent produce if they are not quite sure that it is indeed 'ripe'.

Without the touch of human hand, a new horticultural technology RipeSense™ eliminates this problem by using a sensor label that reacts to the aromas released by fruit as it ripens.

The sensor is initially red and graduates to orange and finally to yellow. By matching the colour to the sensor, consumers choose fruit to the ripeness they prefer.

It's such a clever innovation that TIME magazine recognised it as being one of the world's most amazing inventions of 2004. PHOTO: RIPESENSE.COM

The 'fresh-cut' answer

The consumer's desire for pre-sliced or diced fresh fruits or vegetables with freshness, quality, convenience and low waste has led to the development of the 'fresh-cut' sector in the market. The successful development and sale of fresh-cut products in permeable polymeric film bags, is the most rapidly growing food sector in both North America and Europe.

Consumers are finding that fresh-cut fruit or vegetables that have been trimmed, and/or peeled and/or sliced, diced and cut and packaged as a 100% usable product, offer high nutrition, convenience and flavour while maintaining freshness and minimising waste.

The fresh-cut horticultural segment supplies both the food service industry with large-scale volumes and retail outlets with specialist packs that are suitable for either families or for individual consumers. Salad vegetables make up more than 60% of fresh-cut produce sales.

The most popularly used packaging format is propylene film for bags (or 'pillows') in either 250 and 500 gm packs. Extensible, plasticized PVC is used for tray wrapping. The pillow system is less expensive than other packaging systems having lower labour costs through the use of highly automated filling and weighing processes.

Fresh-cut fruit in a supermarket.

The modified atmosphere solution

The search for better retention of quality led horticultural scientists to the modified atmosphere solution as a means of extending the shelf life of a wide range of fresh products.

This technology substitutes the air inside a package with a protective gas mix. The gas in the packaging (normally a 'pillow') helps to ensure that the product will stay fresh for as long as possible. The modified atmosphere process frequently decreases the oxygen in the package from 20% to less than 5% in order to slow down product metabolism, reduce ethylene production and restrict the growth of fungal rots and the rate of ripening deterioration.

The removed oxygen can also be replaced with enhanced levels of carbon dioxide, which can lower the pH and inhibit the growth of bacteria.

Modified atmosphere conditions within food packages are very effective in prolonging the life and quality of products but it is rarely commercially applied at its maximum potential.

All perishable horticultural products should be stored at optimal temperatures so as to maximise shelf life.

Picked, graded, packed and presented, the crop begins its journey to your door.

Supply chains and cold chains

A supply chain management system is the integration of organization, people, technology, activities, information and resources required to move a product efficiently from a supplier to a customer.

Since most fresh foods are perishable and often require a long process of transport and storage, a special cold chain system is vital.

The infrastructure of a cold chain logistical system generally consists of: pre-cooling facilities, cold storage facilities, refrigerated carriers, packaging, warehousing and information management systems incorporating traceability and tracking.

The best way to maintain quality after harvest is to make sure that food in the supply chain is kept at appropriate low temperatures to reduce spoilage losses and prevent contamination. For most crops grown in temperate climates, product temperatures should be maintained at 0-1ºC for maximum shelf life; for most tropical and subtropical crops temperatures should be above 10ºC to avoid chilling injury. Scientists have established optimal storage conditions for most fruit, vegetables and flowers.

Examples of ideal storage conditions for fruit and vegetables

FRUIT	Temperature range (ºC)	Relative humidity range (%)	Storage time
Apple	-1 to 4.5	90 – 95	4 – 32 wks
Banana – ripe	13.5 to 15	85 – 90	2 – 5 days
Banana – green	12.5 to 21	85 – 95	4 – 21 days
Grapes	-1 to 0	85 – 95	12 – 24 wks
Kiwifruit	-0.5 to 0	90 – 95	8 – 16 wks
Mango	10 to 13	85 – 90	2 – 3 wks
Orange	0 to 9	85 – 90	3 – 16 wks
Pear	-2 to 0	90 – 95	8 – 28 wks
Pineapple	5 to 7	85 – 90	2 – 4 wks
Strawberry	-0.5 to 0	85 – 100	5 – 14 days
Dried fruit	0 to 7	55 – 80	48 wks

VEGETABLES	Temperature range (ºC)	Relative humidity range (%)	Storage time
Asparagus	0 to 2.5	85 – 100	2 – 4 wks
Broccoli	0	90 – 100	1 – 2 wks
Celery	-0.5 to 0	90 – 100	3 – 10 days
Lettuce	0	90 – 100	4 – 16 wks
Mushroom	0	85 – 100	1 – 2 wks
Onion – dry	0	65 – 75	4 – 32 wks
Pea – green	-0.5 to 0	65 – 100	1 – 3 wks
Potato – eating	7 to 12	85 – 100	8 – 32 wks
Pumpkin	10 to 12	70 – 90	8 – 24 wks
Tomato – green	12 to 16	85 – 95	1 – 3 wks
Tomato – firm ripe	6 to 8	85 – 95	3 – 7 days

The cost of not having an effective cold chain is huge – end-to-end

The cost of not getting this right is huge. Because of inefficient cold chain stages during food transport, China incurs losses of 40 billion yuan (US$6 billion) a year from food spoilage.

Pakistan has a fruit and vegetable crop area of 1.4 million hectares and the horticulture sector contributes about 12% to national agricultural GDP. Postharvest losses range between 20% to 40% for horticultural produce and that loss has an estimated value of US$900 million.

Recognising the loss has been the incentive for a US$150 million cold chain system along Pakistan's National Trade corridor involving 23 cold stores, 39 pack houses and 2 reefer (container) yards.

In addition to reducing spoilage losses these improvements are expected to improve shelf life and quality of fresh produce, stabilise prices in domestic markets, increase production surpluses and increase export opportunities.

Other countries are increasingly recognising the scale of fresh food losses that amount to 1.3 billion tonnes worldwide.

In India, where only 2% of products that should be temperature controlled are handled that way, about 30% of the fruit and vegetables grown annually are wasted.

This is due to a lack of awareness about proper handling and storage requirements as well as poor infrastructure, inconsistent electricity supply, insufficient cold storage capacity in close proximity to farms and poor transportation infrastructure.

In China only about 15% of products that should be temperature controlled are handled that way and in the Asia Pacific region only about 8%. This compares with about 85% compliance with good cold chain practices found in Europe and North America.

Avocado exports, Chile.

Cold chains needs to start at the farm with attention to harvest methods, removal from direct sunlight and pre-cooling, and extend right through the chain to the retail and consumer level.

A well organized cold chain reduces spoilage, retains quality of harvested products and guarantees a cost efficient delivery to the consumer, bringing quality and profit benefits to all those linked in the supply chain.

It is an end-to end process and if any of the links is missing or are weak, the whole system can fail.

Cold chain storage, Africa.

Standards for cool chains

In 2003, the Cool Chain Association (CCA), a non-profit organisation, was set up and an industry standard and yardstick for reliability, quality and proficiency in perishable and temperature-sensitive products was established.

The result is an open and auditable industry standard incorporating benchmarking to establish transparent and comparable quality measures for carriers (airlines, road hauliers), handling agents, forwarders, perishable centers, airports and warehouses with long and short-term cold stores.

To be effective and successful, cold chain management systems must have continual monitoring of product temperature throughout distribution and, where there is a problem, there have to be appropriate corrective action plans in place.

Traceability

When there is a breakdown in a supply chain and food or plants degrade, or become contaminated with other substances or carry undesirable insects, then the point of failure must be traced as fast as possible.

This is easier to accomplish if the product carries with it a record of the location of harvest, storage and transport history.

New solutions to supply chain traceability are moving from sophisticated bar code systems to new technology such as Radio Frequency Identification.

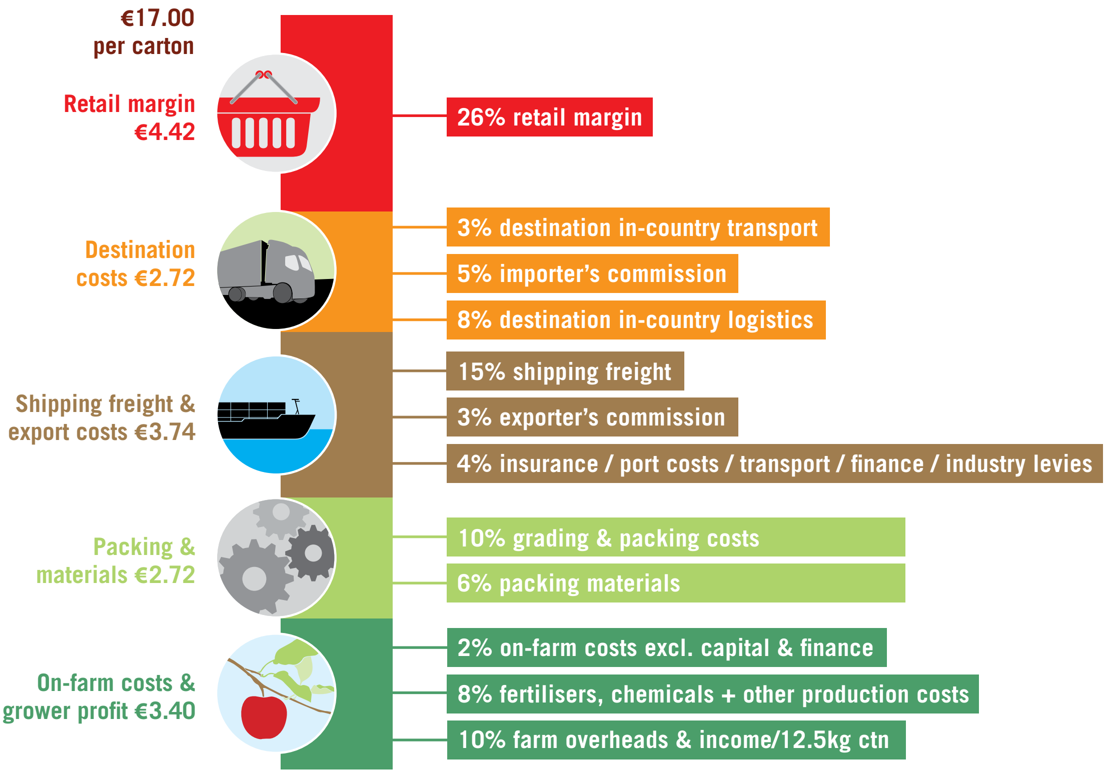
A Radio Frequency Identifier (RFID) is an electronic tag placed in the product which is 'asked' electronically on a truck, train, ship or plane, in a warehouse, or in a storage facility to identify itself and deliver the data it has been programmed to collect.

RFID units embedded with products can provide a real time record of current location, distance travelled, location of origin and information on environmental factors such as temperature, relative humidity and vibration.

In 2009 the Spanish supermarket chain Mercadona with 1,236 supermarkets installed RFID tag readers within the dry, fresh and frozen goods sectors at its centre near Madrid. Wal-Mart the world's largest retailer required all incoming goods to store to have RFIDs by 2010.

Supply chain cost structure

Example based upon apples from Southern Hemisphere retailed for €17.00 per carton (12.5kg) in a European market in 2008 (duty costs excluded)



As shown in the cost structure diagram above, the profit that the grower of the produce receives may only be a small portion (~10%) of the cost that consumers pay at retail. SOURCE: M. DODD, 2008

Thought Challenge #4

The producers of export fruit and vegetables currently receive typically less than 20% of the retail value – an amount less than the retail margin.

Q. What might happen if, through the inadequacy of their incomes, producers cease production?

Fruit and vegetables sold in many different types of markets around the world.

Food safety and biosecurity

Before and throughout their journey to market, horticultural produce may be exposed to microbial and other contamination. Food safety is a major issue for the industry and international trading often requires horticultural growers and exporters to call upon scientific expertise to deal with quarantine and market access issues concerning unwanted pests and diseases.

Border protection and biosecurity authorities using sophisticated systems, set policy and design protocols and use technology to detect residual agri-chemical traces and identify problems of pests and diseases.

Biosecurity postharvest technologies

With few exceptions all produce must use some form of biosecurity technology. A number of technologies have been developed for treatment of fruit after harvest to destroy any unwanted contaminating pests. Of particular concern are the fruit flies that lay their eggs in many varieties of tropical fruit.

Low temperatures for long periods can kill tropical fruit flies, especially if combined with changed atmospheres. The atmosphere surrounding the fruit can be modified either by reducing oxygen or increasing carbon dioxide concentrations (referred to as modified atmosphere, MA, or controlled atmosphere, CA).

Other treatments developed include using heated air, water or steam with temperatures ranging from 45-55°C for 5-110 minutes depending on product, variety and size. Extreme care must be taken to monitor product temperature continuously during treatment to avoid tissue damage.

Such treatments include: hot water treatment, vapour heat or forced-hot air, vapour heat treatment (VHT) and forced hot-air heating treatment (FHAT).

Mangos and papayas are good examples of fruit grown in areas where fruit fly is established. Export of mangos or papayas to another country that does not have such pests, usually requires a quarantine treatment as a phytosanitary measure to ensure that no live fruit fly larvae or insects are present in imported fruit.

Irradiation

Food irradiation is a process where products are exposed to ionizing radiation to sterilize or kill insects and microbial pests by damaging their DNA.

While much of the focus of irradiation use on fruits and vegetables has been for extending shelf-life and reducing decay, irradiation is effective at sterilizing or preventing further development of a range of insect pests on perishable fruits and vegetables.

Irradiation is a capital-intensive technology requiring a substantial initial investment, ranging from US$ 3 million to US$13 million. Radiation plants are costly and would be more economical if used essentially year-round. However, fresh fruit and vegetable production is regional and seasonal.

While studies have shown consumer acceptance of irradiated produce in the USA is increasing, serious public concerns remain about safety of food in other countries where irradiated products are not accepted by consumers.

Handle me with care

From seed to table the efforts of a multitude of individuals and businesses are involved in the safe and presentable delivery of horticultural products to your door to satisfy your requirements. It is a triumph of care and attention, sound and innovative science and the dedication of growers and deliverers alike.

Post-harvest sorting, grading and storage require sophisticated, highly technical facilities to manage large volumes of produce and to meet safety and quality standards. (Left) avocados, Chile and (right) apples, New Zealand.

Ultra high pressure (UHP) technology

Ultra high pressure (UHP) technology is a non-thermal cold pasteurization technique using pressures up to 87,000 psi to shock and kill bacteria in food products.

The process is said to have the same inactivating effect on micro-organisms as heat or chemicals, but with no effect on taste, texture, colour, nutritional value or the vitamin content of the food.

When used on avocados, UHP extends the product life from 30 days to 60 days and the resulting paste is suitable for spreads and guacamole. UHP can also modify physical and rheological properties of proteins, which could lead to the development of new pressurised products with applications in food technology and as an ingredient in other food presentations.

Thought Challenge #5

Governments are reducing and in some countries are terminating information transfer services for technical and production knowledge available to farmers (with examples being New Zealand and the United Kingdom).

Q. Might there be increased risk of food safety crises and major plant disease outbreaks as a result of the near total absence of expertise in such technical transfer services?