New Strategies in Transportation for Floricultural Crops

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Abstract

In the past century, the centers of production and consumption of ornamentals increasingly have become widely separated. A cut flower bouquet purchased today in a Verona florist could easily combine Italian foliage with flowers grown in Kenya, Colombia, Holland and Thailand. The extended transportation infrastructure and delays between harvest and consumption implicit in this separation can easily result in significant reduction in quality and vase life. Geography plays an important role in selection of transportation mode, and most "long distance" flowers still are transported by air. Air transport typically results in quality loss due to poor temperature control, accelerated water loss, and airport delays and interventions. The high Q_{10} for respiration in cut flowers (as much as 7!) implies a substantial premium for careful temperature control during transportation. Innovative systems for temperature control could be important tools for maintaining freshness during air transport. The primacy of postharvest temperature control has driven the continued search for ways to use surface transportation - sea containers and trucks are an important tool in this effort. The lack of response of cut flowers to controlled atmospheres (apart from ethylene-sensitive flowers) has frustrated this effort, but careful temperature control and monitoring of container temperatures and the use of faster ships has resulted in successful out-turn of flowers transported from Central America to North America. Temperature control also frustrates efforts to direct-market flowers using the Internet. Innovative packaging concepts will be essential to success in this field.

THE CONSUMPTION OF CUT FLOWERS IN THE U.S. IS LOW

The world market for cut flowers is a dynamic one, with major changes in consumption and production in relatively short time-scales. Of particular interest has been the evolution of the market in the United States, which is illustrated by statistics provided by the USDA Market Research Service (Fig. 1). In brief, the data show:

- In the early 70's, with the entry of significant quantities of imported flowers, consumption rose.
- U.S. production was static until the early 90's, while consumption increased with steady increase in imported product.
- During the 90's the unfavorable comparative economics of production in the U.S. (primarily California) resulted in a rapid decline in local production, which now represents less than 30% of all the flowers consumed in this country.
- From the mid-90's, consumption of cut flowers fell steadily, and by 2000 was less than three quarters of that at the peak (1993).

PER CAPITA CONSUMPTION OF FLOWERS IN THE U.S. LAGS BEHIND THAT IN OTHER COUNTRIES

Comparison of U.S. and international statistics show the nature of the problem for the cut flower industry in the U.S. Per capita consumption of cut flowers in the United States is very low compared to other developed, and even some developing nations (Table 1). For example, consumption in Holland is 24 times higher, and even in Britain, a nation that historically has had relatively low cut flower sales, present consumption is 16 times that in the U.S. Despite the high standard of living and historically high levels of disposable income in the U.S., cut flower consumption is lower than that in Poland and

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Russia. The problem is largely one for the cut flower industry, since potted plant sales in the U.S., while less than in Holland, are greater than those in the U.K. and much greater than those in Poland and Russia.

It is our thesis that this low per-capita consumption is the result of two inter-related problems; a culture of low personal use, and a general dissatisfaction with the quality of cut flowers. In the U.S., flowers still largely supply the holiday and special events businesses, and the industry has failed to generate a culture of using flowers as an every day accoutrement. Sporadic efforts by the industry to increase sales through marketing campaigns have been doomed to failure because the flowers that are on offer give poor customer satisfaction. Research data, and legions of anecdotal accounts indicate that the life of purchased cut flowers is highly variable. We have demonstrated clearly that flower life in the consumer's home is determined by the time/temperature exposure of the flowers prior to sale (Cevallos and Reid, 1998). The fact that the majority of the cut flowers sold in the U.S. are produced at great distances from the consumer demands a rigor in temperature management and speed of delivery that is presently lacking in our distribution system. The industry focus on major holidays encourages long-term storage of flowers that exacerbates the problem (the peak harvest for Valentine's Day roses, for example, occurs in late January). The fact that declining per capita consumption of cut flowers mirrors the increased percentage of flowers that are produced off-shore (and therefore transported long distances, usually without refrigeration) may be no accident.

CUT FLOWER CONSUMPTION CAN BE CHANGED RAPIDLY

One other statistic from the Flower Council of Holland (Voermans, M., pers. comm.) should be a clarion call to the U.S. industry. In the past 5 years, the consumption of cut flowers in the United Kingdom has doubled. This doubling has been the result of their industry addressing the two issues that are the root cause of low consumption in the U.S. Advertising campaigns in the U.K. has focused on increased personal use (focused, particularly on women - 'buy some flowers for yourself'). In parallel, major supermarket chains have become the primary source of cut flowers, and have instituted systems for management and control of quality that ensure that the customer receives a satisfactory product. These companies source flowers from farms in Kenya and Zimbabwe where product of predetermined quality is packed ready for sale, with prices and harvest and sell-by dates marked on sleeves. Temperature is controlled and monitored throughout the postharvest chain, and visual and vase-life quality are routinely tested on arrival in Britain.

INCREASING CONSUMPTION DEPENDS ON BETTER TRANSPORTATION

If U.S. consumption could be doubled, as in the U.K., changes in the demand/supply equation would improve the economics of the cut flower industry for everyone - producers, shippers, retail florists and supermarkets. To achieve such growth, the industry needs to address the two key issues; providing consumers with flowers that will last in their homes, and promoting a culture of personal use of flowers for everyday enjoyment. To provide consumers with long-lasting flowers, it is clear that the industry needs to improve temperature control during long-distance transportation of flowers that is the norm in the U.S. market. The present poor temperature control that is common in the industry is not due to lack of innovative systems for refrigerated transportation. Whether flowers are shipped by air, by sea, or by land, equipment is available that can ensure temperature management throughout the chain.

INNOVATIVE TRANSPORTATION SOLUTIONS ARE ALREADY AVAILABLE

Since the majority of the flowers sold in the U.S. (and, indeed, globally) are transported by air, the industry has relied on the speed of air transport to offset the poor temperature management (and accelerated desiccation) that is implicit in present air cargo systems. Inadequate precooling before transport, delays and high temperature conditions at originating and destination airports, customs, drug, and quarantine inspections, all lead to poor temperature management during the transportation chain. While the actual flight time may be as little as two to three hours, overall time from harvest to establishment of proper temperature conditions may be one to two days.

Improving the temperature management of air-freighted flowers can be achieved using current technologies. Active CO_2-based refrigerated containers (Envirotainer™ - http://www.envirotainer.com/) have been available for a number of years, and a passive refrigerated container produced by Nomos™ was demonstrated at this conference. Proper precooling, palletizing, and wrapping pallets with polyethylene covers to reduce air infiltration can result in relatively little temperature gain during air transport. The problem, in our estimation, has not been the lack of equipment capable of maintaining flowers at the correct temperature, but rather the failure to recognize the importance of temperature management, and the lack of effective tools to monitor flower condition. In the U.S. market, there is presently no effort to monitor temperature during the transportation chain, and marketers have no tools to allow them to determine potential vase life of product that they receive. Our research is focused on providing such tools, in the expectation that recognition of the importance of temperature management in maintaining freshness will encourage the effective use of existing and innovative transportation technologies.

INEXPENSIVE TIME-TEMPERATURE INTEGRATORS

Although many companies transporting cut flowers by truck provide datalogger information on truck temperatures, these data are usually a reflection of the exit air from the evaporator unit, and may not reflect temperature conditions in the product. Temperature monitoring is seldom implemented for flowers transported by air. We have worked with Vitsab™ Inc. to implement enzyme-based time-temperature integrators that can be used by the floral industry to monitor adverse temperature exposure of flowers during distribution. The integrators (Fig. 2) include three enzyme/substrate 'windows' and when the strip is activated (by crushing), the enzyme /substrate mixture in each window is green. The rate of conversion of the green substrate to a yellow product depends on the concentration of the enzyme, temperature and time. The strips that we have tested for use with cut flowers have windows with enzyme content that results in the color change (green to yellow) occurring after 1, 2, or 4 days exposure to temperatures above 40°F (5°C). Preliminary trials have indicated a good correlation between the 'reading' of the integrators and the time-temperature history of flowers determined from digital dataloggers included in the flowers.

DEVELOPING TOOLS FOR TESTING FLOWER FRESHNESS

A fundamental problem to ensuring the freshness and vase life of cut flowers is that there is no easy way for a receiver (wholesaler, retailer, or consumer) to tell what abuse a flower may have suffered during its transportation and storage. Flowers that are close to the end of their potential life after poor handling and temperature management may not be visually different from flowers that have been correctly handled. This is a problem for the industry, because it means that it is the customer who finds out whether the flowers are fresh or old. Few cut flower marketing companies in the U.S. have ever implemented a strict quality control program (where sample flowers would be placed in vases under controlled conditions) because of space and manpower limitations.

Identification kits using enzymatic, antibody, or molecular methods are increasingly sophisticated and continue to decrease in cost. A pregnancy test that used to require a clinician, expensive equipment and came with a substantial bill can now be conducted with an inexpensive kit purchased over the counter. Our research is investigating the possibility that a simple test could be developed to evaluate the freshness of cut flowers.

A number of researchers have reported changes in abundance of gene transcripts during flower senescence (for review, see Hunter et al., 2004). Some of these genes are common to a range of the cut flower systems that have been studied (Jones, 2004; Breeze et al., 2004) (Table 2). We are selecting for further study, genes that are present in a number of systems, that show strong up-regulation during floral senescence, and are specific to petals. Using quantitative real-time PCR, we have started to examine changes in selected genes during senescence of a range of commercial cut flowers. Table 3, for example shows results for changes in the abundance of transcripts (gene copies) of one of the candidate genes (SR12) during senescence of carnation petals.

The dramatic rise in transcript abundance of this gene as senescence commences indicates the potential of this tool for determining the freshness of cut flowers. In continuing research, we intend to examine a wide range of genes, not only for a strong negative correlation between transcript abundance and remaining vase life, but also for usefulness with a diversity of commercial cut flowers. Once we have identified such a gene or genes, we will be ready to develop a test 'kit' that will enable inexpensive determination of vase life potential at the wholesale and retail level.

CONCLUSIONS

The statistics clearly demonstrate a need to increase consumer satisfaction if cut flower sales are to increase on the U.S. flower market. We feel that the optimal strategy to ensure the adoption of effective temperature management during transportation is to place tools for determining quality in the hands of the receivers and consumers. Inexpensive time/temperature monitors are already available for this purpose, and we expect that our continuing research directed towards 'freshness indicators' will provide another tool to ensure that cut flowers and other ornamentals are as fresh as possible on delivery to the ultimate consumer.

ACKNOWLEDGMENTS

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Literature Cited

Breeze, E., Wagstaff, C., Harrison, E., Bramke, I., Rogers, H., Steady, A., Thomas, B., and Buchanan-Wollaston, V. 2004. Gene expression patterns to define stages of post-harvest senescence in *Alstroemeria* petals. Plant Biotechnol. J. 2: 155-168.

Cevallos, J.C. and Reid, M.S. 2000. Effects of temperature on the respiration and vase life of Narcissus flowers. Acta Hort. 517:335-342.

Hunter, D.A., Lange, N.E., and Reid, M.S. 2004. Physiology of Flower Senescence. p.307-318. In: L.D. Nooden (ed.), Plant Cell Death Processes, Elsevier Science, USA.

Jones, M.L. 2004. Changes in gene expression during senescence. p.51-71. In: L.D. Nooden (ed.), Plant Cell Death Processes, Elsevier Science, USA.

Tables

Table 1. Per capita consumption of cut flowers in 2002 for different countries. Constructed with information from the USDA Market Research Service and from the Flower Council of Holland (Voermans, M., pers. comm.).

Country	U.S.	Holland	United Kingdom	Poland	Russia
Cut flower sales (per capita)	$3	$72	$48	$8	$4
Potted plant sales (per capita)	$16	$40	$14	$4	$1

Table 2. Genes that show up-regulation during petal senescence.

Gene	Species	Homolog	Expression		Induction
			Lvs	*Flwrs*	
SR120	Carnation	ACC oxidase	No	Up	C_2H_4
DCACS1	Carnation	ACC oxidase	No	Up	C_2H_4
DCACS2	Carnation	ACC oxidase	No	Up	C_2H_4
DCACS3	Carnation	ACC oxidase	No	Up	Pollination
DSA4	Daylily	Aspartic protease	No	Up	ABA
SR12	Carnation	β-galactosidase	No	Up	C_2H_4
SR5	Carnation	β-glucosidase	No	Up	C_2H_4
SR132	Carnation	CPP mutase	ND	Up	
DCCP1	Carnation	Cysteine protease	Up	Up	C_2H_4
Sen102	Daylily	Cysteine protease	No	Up	
Sen11	Daylily	Cysteine protease	No	Up	
Peth1	Petunia	Cysteine protease	Up	Up	
SR8	Carnation	GST	No	Up	C_2H_4
Lipase	Carnation	Lipase	Up	Up	C_2H_4
Rlos1	Rose	Lipoxygenase	ND	Up	C_2H_4
DSA6	Daylily	S1 nuclease	No	Up	ABA
MtN19	Alstroemeria	Unknown protein	NA	Up	
MT1	Alstroemeria	Metallothionein	NA	Up	

Table 3. Real-time PCR measurement of abundance of transcripts for a senescence-associated gene (SR-12) from carnation petals.

Flower stage	Transcript abundance (relative to bud-stage)
Bud-stage	1
Newly opened flower	2.5
2-day old flower	3.9
Incipient senescence	590

<u>**Figures**</u>

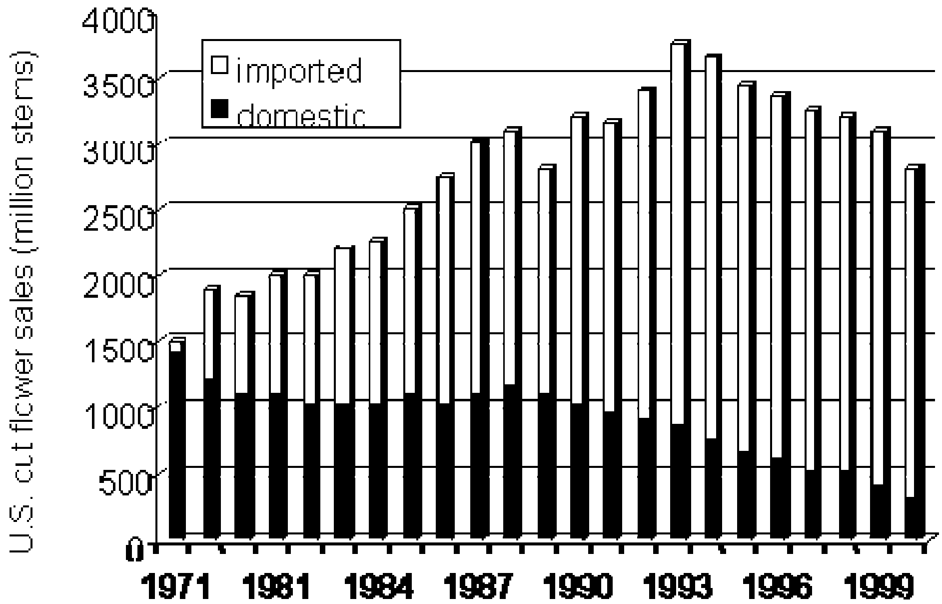

Fig. 1. Source and sales of cut flowers in the U.S. during the last three decades. Data obtained from the USDA Marketing Research Service.

Fig. 2. 'Vitsab' three-window time/temperature integrator implemented for use with cut flowers.