

**A Comparison of Quality Attributes in ‘AU Golden Dragon’, ‘AU Golden Sunshine’, and ‘Hort 16A’ Kiwifruit (*Actinidia chinensis*) During Storage**

by

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## Abstract

This research focused on the effects of fruit size and cultivar on fruit quality and postharvest storage life of three cultivars of *Actinidia chinensis*. In the first experiment, the fruit quality attributes of ‘AU Golden Dragon’, ‘AU Golden Sunshine’ and ‘Hort 16A’ were determined for three different sizes of kiwifruit over 14 weeks in cold storage. Soluble solids (SS) content, SS:titratable acidity (SS:TA), internal color and external color development increased as fruit firmness and titratable acidity decreased due to time in cold storage. Based on fruit firmness results, smaller sized *A. chinensis* fruit appear to have greater cold storage life potential than larger sized fruit. In the second experiment, fruit quality attributes and storage life of ‘AU Golden Sunshine’ was compared to ‘Hort 16A’. ‘Hort 16A’ fruit had a greater SS, SS:TA and percent dry weight (% DW) compared to ‘AU Golden Sunshine’. ‘AU Golden Sunshine’ and ‘Hort 16A’ fruit were stored for 14 weeks before firmness decreased below optimum eating quality.

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## List of Abbreviations

AU	Auburn University
F	Fahrenheit
%	Percent
C	Celsius
mg	Milligram
g	Gram
Ha	Hectare
kg	Kilogram
SS	Soluble solids
IC	Internal Color
EC	External Color
%DM	Percent Dry Matter
TA	Titrateable Acidity
SS:TA	Soluble solids: Titrateable acidity
DW	Dry Weight
FW	Fresh Weight
ml	Milliliters

## **CHAPTER I**

### **Literature Review**

#### **Origin of Kiwifruit**

The kiwifruit vine is native to Southeast Asia. It grows wild in parts of China, most commonly in the forest margins of the Yangtze River Valley where it grows to a height of 30 feet or more (La Rue, 1994). Kiwifruit has had several names throughout its history. It was first called “monkey peach” during the Tang Dynasty due to the fact that the Chinese would observe wild monkeys eating the ripe fruit. Next it was called Chinese gooseberry; Chinese because of its origins in China, and gooseberry because of its closeness in flavor to the European gooseberry (Ferguson, 2004). Lastly, and currently, it is called kiwifruit in honor of the native Kiwi bird that is a symbol of New Zealand, and not because of any similarity to the brown fuzzy appearance of the bird (Ferguson, 2004).

In 1899, the English nursery of James Veitch and sons sent E.H. Wilson to China to look for moderate climate plants that could be brought back to England and used in private gardens (Ferguson, 2004). Kiwifruit seeds were also sent to England and the United States in 1900 and those seeds were used to grow ornamental plants for personal estates, not on a commercial fruit production basis. This was because kiwifruit are dioecious, and therefore require separate male and female plants to produce fruit (Ferguson, 2004). Wilson was also responsible for introducing kiwifruit to all of the



westerners that were living in Ichang, China. One of these resident westerners, Katie Fisher, brought the seeds to New Zealand in the early 20<sup>th</sup> century (Ferguson, 2004; La Rue, 1994). Those seeds that were brought back to New Zealand were given to Alexander Allison who grew them in Wanganui, New Zealand, where the new vines first successfully fruited in 1910 (LaRue, 1994). It is believed that all other kiwifruit grown in New Zealand are descended from those first vines (LaRue, 1994). The United States Department of Agriculture brought kiwifruit to America in the early 1930's as a potential crop that was adaptable to the southern and western United States (La Rue, 1994).

Kiwifruit were launched into the world market in 1960 and has made rapid progress since then in both the number of cultivars and availability (Nishiyama, 2007). Kiwifruit are now common and easily obtainable throughout the year around the world. Kiwifruit is one of only four new fruit crops introduced to international trade in the twentieth century (Nishiyama, 2007). They have been grown in many countries, notably Italy, China, New Zealand, Chile, France, Greece, Japan, and the United States (Nishiyama, 2007). As of 2008, the top three producers of kiwifruit are Italy with 473,955 tons produced at a value of \$258,523,000 dollars, New Zealand with 365,000 tons produced at a value of \$199,092,000 dollars, and Chile at 170,000 tons produced at a value of \$92,728,000 dollars (FAOSTAT, 2010).

Kiwifruit first came to California in the United States in 1960 and has grown from 50 acres in 1970, to 4,300 acres in 2006 (Mainland and Fisk, 2006). In the eastern United States, kiwifruit vines have fruited in Virginia Beach, Virginia, at several locations in South Carolina, and are part of evaluation programs in Alabama and Georgia. The first commercial shipments began in 1980 from a planting in South Carolina located about 30

miles north of Augusta, Georgia. In North Carolina, several vines were planted at a research farm near Raleigh in the early 1970s, but these did not survive the first winter (Mainland and Fisk, 2006).

*Actinidia* kiwifruit currently has 76 species and 130 different taxa (Ferguson 1991). Not all kiwifruit are similar, as there are differences in size, external hairiness, external color, internal color, sweetness, storage parameters, and chilling hours (Bliss, 1994). Kiwifruit are also a very healthy addition to a daily diet due to high amounts of vitamin C, vitamin E, folic acid, and various phytochemical such as anthocyanidins and flavonols (Wen-Hsin and Liu, 2009).

### ***Actinidia deliciosa* ‘Hayward’**

Presently, the most common commercial cultivar in the world is *Actinidia deliciosa* ‘Hayward’ (Ferguson, 1991). ‘Hayward’ kiwifruit is the most popular cultivar due to its large fruit, green color, unique flavor, and ample shelf life for shipping worldwide (Ferguson, 1999). ‘Hayward’ kiwifruit was developed by a horticulturist named Mr. Hayward Wright in New Zealand. ‘Hayward’ was selected in 1925 out of a seedling population. The one plant that Wright developed is the ancestor of all of the ‘Hayward’ plants grown in the world today (Ferguson, 1999).

### **Growing ‘Hayward’ Kiwifruit**

‘Hayward’ is best grown in temperate climates where winters provide at least 950 chilling hours for vegetative bud break and 1150 chilling hours for optimum flowering (Caldwell, 1998). A chilling hour is an hour where the temperature remains at or below

45° and above 32° F (Hindrick and Powell, 1998). Kiwifruit should be grown in a vineyard that has quality soil with good drainage and an adequate supply of water, as the summer requirements can be up to 13000 gallons an acre/day (Norton, 1994). 'Hayward' is best grown on a T- bar or pergola trellis system due to the vine growth habits of 6-12 feet / year (Reil, 1994). The kiwifruit vines can be propagated by grafting onto a rootstock or via cuttings.

'Hayward' kiwifruit increases in size and dry weight throughout the entire growing season, as well as slowly increases in soluble solids. The most rapid growth is made during the first 100 days after bloom (Mitchell, 1994). 'Hayward' fruit typically has an acidity above 2% at harvest and a low % SS of 6.5. The low % SS and acidity of 2.5% gives the 'Hayward' kiwifruit its signature sour flavor at harvest (Mitchell, 1994). Harvest is determined in New Zealand based on a soluble solid content of 6.2-6.5 %. The acidity at harvest is up to 2.5 % with 40-50 % being citrate acid, 40-50 % as quinate acid and 10 % as malate acid, which accounts for the sour flavor for which 'Hayward' kiwifruit is known (Hall et al., 2006; Marsh et al., 2004). 'Hayward' kiwifruit has an average vitamin C content of  $65.5 \pm 14.2$  mg/100g fresh weight (Nishiyama, 2007). Seed set as well as the overall number and size of fruit is dependent on the amount of fertilization that occurred on that vine, but a typical 100g fruit can have more than 1000 seeds (Grant, 1994; Salinero et al., 2009).

### **Storage of 'Hayward'**

Most research in kiwifruit has been conducted on the 'Hayward' kiwifruit, as it is the current industry standard. 'Hayward' has a storage life of three to six months, which

is one of its more valuable attributes (Nishiyama, 2007). The optimum kiwifruit storage temperature to slow down the process of ripening is at 0 °C (Lallu, 1989). When the firmness of the kiwifruit reaches 1.2 kg of pressure at pre-shipment for retail, that kiwifruit is considered past its prime. This is because ‘ Hayward’ kiwifruit shipped at 1.2 kg results in a pressure of 0.6 - 0.8 kg at market. With the optimum eating pressure at 0.7 kg, fruit firmness ranging from 0.6 - 0.8 kg is considered too close to unmarketable (Lallu, 1989; Lallu, 1997). Kiwifruit stored at 20 °C is able to ripen at the same rate as kiwifruit exposed to an ethylene treatment and then stored for 6 weeks at 0 °C (MacRae et al., 1989). Pre-cooling in an ambient room temperature prior to cold storage did not increase the amount of ethylene or the softening in kiwifruit (Retamales et al., 1997).

In cold storage (0 °C), the soluble solids concentration of kiwifruit increases while acidity and firmness decreases (MacRae et al., 1989). An ethylene treatment will quickly soften and ripen kiwifruit at a uniform rate, but storing the kiwifruit at 0 °C after an ethylene exposure caused a controlled slowing of the rate of softening and ripening (Lallu et al., 1989). Kiwifruit stored at 0 °C also had a leveling effect on the amount of malic acid, unlike higher storage temperatures (Marsh et al., 2004). Storage of kiwifruit above 0 °C appears to increase the malic acid levels to increase the sour flavor of the kiwifruit (Marsh et al., 2004).

Sensory panels that compared kiwifruit with different percent dry weight (% DW) content preferred the kiwifruit with higher percent dry weight (Burdon et al., 2004; Jaeger et al., 2011). Kiwifruit was also preferred by groups of panelists when the sugar content is 12.5 to 15.5 % or higher at market, and thought to have a sour flavor when the sugar is below 11.6 %, with the highest “liking” between 16 and 18 % DW (Burdon et

al., 2004; Crisosto and Crisosto, 2001; Harker et al., 2009; Jaeger et al., 2011). The % DW in 'Hayward' kiwifruit adds many of the flavors and aroma that consumer panels prefer (Burdon et al., 2004; Crisosto and Crisosto, 2001; Nardozza et al., 2010a; Nardozza et al., 2010b). When comparing large and small fruit in both a low and high % DW *A. delicosia* genotype, panelists prefer the high % DW large kiwifruit that were perceived as having a greater tropical flavor and sweetness (Nardozza et al., 2010b). The higher % DW kiwifruit was also seen as being juicier than the lower % DW kiwifruit (Nardozza et al., 2010b). This is due to the cell size and dilution factor of the starch within the cells. Larger cells dilute the starch greater than the small cells (Nardozza et al., 2010a; Nardozza et al., 2010b; Nardozza et al., 2011). Higher % DW kiwifruit was composed of 50% small cells and 43 % large cells, compared to the low DW kiwifruit that had 43% small cells and 51% large (Nardozza et al., 2011)

Storage at 0 °C has a significant effect on the kiwifruit producing a higher percent dry weight and percent soluble solids as well as a lower percent acidity (Marsh et al., 2004). Percent dry weight and the % SS content of the kiwifruit, which adds to the sweet flavor, is an important factor when comparing cultivars and consumer evaluations of kiwifruit cultivars (Burdon et al., 2004; Jordan et al., 2000). Proper storage at 0 °C helps to produce the desirable sugar to acid ratio that consumers prefer (Marsh et al., 2004). Consumers are able to perceive kiwifruit for its sweetness and a high % SS can cover up or suppress any undesirable effects of acidity that causes sour flavor (Rossiter et al., 2000; Nardozza et al., 2010b). The aroma volatiles, which are important factor in perceiving taste, increased in fruit that has been stored at 0 °C prior to shelf life in a retail setting (Paterson et al., 1991; Rossiter et al., 2000).

### ***Actinidia chinensis* ‘Hort 16A’**

In 1995, Hort Research, a research and development firm working on behalf of Zespri Inc. in New Zealand, introduced a golden kiwifruit cultivar to the market named *A. chinensis* ‘Hort 16A’ (Patterson et al., 2003). During the development of the golden kiwifruit and up until 1984, *A. chinensis* was classified as the same species as *Actinidia deliciosa*, but *A. chinensis* was determined to be a different species because of its physical and internal qualities (Nishiyama, 2007). The yellow color is attributed to the lack of chlorophyll ranging from 0.05 - 0.73 mg/100 g of fresh weight. Low chlorophyll also contributed to the transformation from chloroplasts to chromoplasts (McGhie and Ainge, 2002).

Approximately 2000 ha have been planted in New Zealand since the introduction of ‘Hort 16A’, and it is currently being planted in Italy, United States, and Japan under the commercial trade name, licensed by Zespri™, Zespri™ Gold (Patterson et al., 2003). ‘Hort 16A’ has been a successful crop in New Zealand where ‘Hort 16A’ now accounts for 17 - 18 % of New Zealand’s kiwifruit exports (Nishiyama, 2007).

### **Growing ‘Hort 16A’**

As with the ‘Hayward’ cultivars, ‘Hort 16A’ is a dioecious plant, meaning that there are separate male and female plants needed for pollination. The pollination of the kiwifruit is essential to fruit set, fruit quality, and fruit size (Patterson et al., 2003). ‘Hort 16A’ is a rapidly growing fruit, putting on as much as 1.6 grams of weight a day between days 40-50 after pollination, adding up to 1.1 grams a day between 40- 80 days after

pollination, and up to 0.5 grams a day from 100-120 (Patterson et al., 2003). 'Hort 16A' is sweeter, with a soluble solid content of 9-14% at harvest, when compared to 'Hayward' which is harvested at 6.5% SS content. This higher % SS content at harvest allows 'Hort 16A' to be edible right at harvest (Clark et al., 2004; Mitchell, 1994). 'Hort 16A' has been described as having flavors that are tropical, sweet, like blackcurrant, aromatic melon, candy floss, and fruit candy (Harker et al., 2009; Harker et al., 2007; Jaeger et al., 2003). The optimal kiwifruit pressure for consuming 'Hort 16A' is between 0.5 and 1 kg of pressure (Patterson et al., 2003). The harvest of 'Hort 16A' usually occurs about a month earlier than 'Hayward'. 'Hort 16A' is softer and has a pronounced beak on the end that requires modifying harvesting techniques used for 'Hayward' kiwifruit (Patterson et al., 2003).

### **Storage of 'Hort 16A'**

Similar to 'Hayward' kiwifruit, the % SS tend to increase during storage. A consumer preference study determined that 80% of panelists tested preferred 'Hort 16A' when the % SS was at or above 14% and % DW at or above 16% (Harker et al., 2009). The softening of the 'Hort 16A' kiwifruit occurs in two phases. The first rapid decrease can take 10 weeks to get to 1 kg of pressure. The second, slower softening, occurs over the final storage time (Patterson et al., 2003). Kiwifruit softens during its time in cold storage as a result of changes in the metabolic pathways within the cells that result in an increase in volatile chemicals and a breakdown of cell walls causing the fruit to soften, become more fragrant, and more juicy (Harker et al., 2009). Proper nutrient applications of nitrogen, potassium, magnesium, sulfur, calcium, and phosphorus during the growing

season can help in lengthening storage potential of 'Hort 16A' (Millis et al., 2008). The expected storage life of 'Hort 16A' is between 12-16 weeks if the temperature is kept at or near 0 °C (Patterson et al., 2003).

There is a potential for chilling injury if certain criteria are not met. Chilling injury is an injury due to the length of storage as well as the temperature. Generally, the longer the cold storage time, the greater the chance for chilling injury (Lallu, 1997; Maguire et al., 2007)). In kiwifruit the main factor in chilling injury is thought to be the % SS content below 6.2 at harvest and cold storage at 0 °C (Crisosto and Crisosto, 2001; Lallu, 1997). Chilling injury can result in a mealy, gritty fruit with a low juice content and leathery texture (Lallu, 1997).

Placement on the kiwifruit vine itself can also play a part in the maturity and chilling injury of 'Hort 16A' (Maguire et al 2007). 'Hort 16A' had a difference in % SS, % DW and internal color when kiwifruit were compared from the outer edge and under the canopy of the same vine (Maguire et al., 2007). This low % SS in immature kiwifruit has a high likelihood of chilling injury if stored for a long duration at 0 °C (Maguire et al., 2007)

### **'AU Golden Dragon' and 'AU Golden Sunshine'**

Two new cultivars of *A. chinensis* have been developed in a joint effort between Auburn University and Institute of Fruit and Tea, Hubei province, P.R. China. 'AU Golden Dragon' and 'AU Golden Sunshine' have been evaluated at the Chilton Research and Extension Center in Clanton, Alabama since 1995 (Wall, 2006). The new cultivars of golden kiwifruit could bring a boost to the Alabama economy. There is a potential net



return of \$10,765 dollars an acre (Burnie, 2009). In New Zealand, golden kiwifruit is a 160 million dollar industry that accounts for 17 - 18% of New Zealand's total kiwifruit exportation (Nishayama, 2007). In Alabama, the traditional crop of cotton brings in an average return of \$324 dollars per acre (Nation Cotton Counsel, 2010). If Alabama grew 465 acres of kiwi at the current \$6.00/tray, with predictions of 6000 trays per acre, it would bring in a potential 16 million in revenue (Burnie, 2009).

These two new cultivars have different bloom and harvest times compared to 'Hort 16A' allowing for the seasonal availability of golden kiwifruit to be extended (Burnie 2009). This would be beneficial and well accepted according to Jaegar et al., (2003), where it is stated that development of early or late maturing selections similar to 'Hort 16A', will supply exports with yellow kiwifruit for a longer period of time and sustain consumer interest in the yellow kiwifruit. The other reason for the different harvest and bloom times is the chilling hours that the 'AU Golden Dragon' and the 'AU Golden Sunshine' require. In a study by Wall et al. (2008), 'AU Golden Dragon' dormant bud rest was achieved with 800 h of chilling. Dormant bud rest was achieved with 700 h of chilling for 'AU Golden Sunshine' (Wall et al., 2008).

## Literature Cited

- Bliss, F. A. 1994. The genus *Actinidia*, p 9-10. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). Kiwifruit Growing and Handling. ANR Publ: Oakland,CA.
- Burdon, J., D. McLeod, N. Lallu, J. Gamble, M. Petley, and A. Gunson. 2004. Consumer evaluation of 'Hayward' kiwifruit of different at harvest dry matter contents. *Postharvest Biol. and Technol.* 34:245-255.
- Burnie, D. A.2009. Economic feasibility of new kiwifruit cultivars for commercial planting in Alabama. Auburn University, Auburn, Alabama, Masters Thesis.
- Caldwell, J. 1989. Kiwifruit performance in South Carolina and Effect of Winter Chilling. Clemson University, Clemson South Carolina.
- Clark, C.J., V.A. McGone, H.N. De Silva, M.A. Manning, J. Burdon, and A.D. Mowat. 2004. Prediction of storage disorders of kiwifruit (*Actinidia chinensis*) based on visible-NIR spectral characteristics at harvest. *Postharvest Biol. and Technol.* 32:147-158.
- Crisosto, C.H. and G. M. Crisosto. 2001. Understanding consumer acceptance of early harvested 'Hayward' kiwifruit. *Postharvest Biol. and Technol.* 22:205-213.
- FAO STAT. 2010. Top Production Kiwifruit 2008. Food and Agriculture Organization of the United Nations. Available: <http://faostat.fao.org/site/339/default.aspx>. (2010, November 6th).
- Ferguson, A.R. 1991. Kiwifruit *Actinidia*. *Acta. Hortic* 290:603-653.
- Ferguson, A.R. 1999. Kiwifruit cultivars: Breeding and selection. *Acta. Hortic* 498:43-51.
- Ferguson, A.R. 2004. 1904- The year kiwifruit *Actinidia deliciosa* came to New Zealand. *J. Crop. Hort. Sci.* 32:3-27.
- Grant, J. A., V. S. Polito, and K. Ryugo. 1994. Flower and fruit development, p 14-17. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). Kiwifruit Growing and Handling. ANR Publ: Oakland,CA.

- Hall, A.J., A.C. Richardson, and W.P. Snelgar. 2006. Modeling fruit development in 'Hayward' kiwifruit. *Acta. Hort.* 707:41-47.
- Harker, F.R. 2004. Consumer evaluation of taste and flavor: Zespri Gold and Zespri Green. *Hort Research.* 166: 5-9.
- Harker, F.R., B.T. Carr, M. Lenjo, E.A. MacRae, W.V. Wismer, K.B. Marsh, M. Williams, A. White, C.M. Lund, S.B. Walker, F.A. Gunson and R.B. Pereira. 2009. Consumer liking for kiwifruit flavor: A meta-analysis of five studies on fruit quality. *J. Food. Qual. And Pref.* 20:30-41.
- Himelrick, D. G. and Powell, A. 1998. Kiwifruit production guide. Published by Ala. Coop. Ext. System. Publication number ANR-1084.
- Jaeger, S.R., K.L. Rossiter, W.V. Wismer, and F.R. Harker. 2003. Consumer driven product development in the kiwifruit industry. *Food quality and preference.* 14: 187-198.
- Jaeger, S.R. R. Harker, C.M. Triggs, A. Gunson, R.L. Campbell, R. Jackman, and C. Requejo-Jackman. 2011. Determining consumer purchase intentions: The importance of dry matter, size, and price of kiwifruit. *J. of Food Sci.* 76:177-184.
- Jordan, R. B., E. F. Walton, K. U. Klages, and R. J. Seelye. 2000. Postharvest fruit density as an indicator of dry matter and ripened soluble solids of kiwifruit. *Postharvest Biol. and Technol.* 20:163-173.
- Lallu, N. 1997. Low temperature breakdown in kiwifruit. *Acta. Hort.* 2:579-585.
- Lallu, N., A. N. Searle, and E. A. MacRae. 1989. An investigation of ripening and handling strategies for early season kiwifruit *Actinidia deliciosa* 'Hayward'. *J. Sci. Food Agric.* 47:387-400.
- LaRue, J.H. 1994. History and commercial development, p. 1-3. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling.* ANR Publ: Oakland,CA.
- Mainland, C. and C. Fisk. 2006. Kiwifruit. North Carolina State University Horticulture leaflet 208. Available at: <http://www.ces.ncsu.edu/depts/hort/hil/hil-208.html> (2010, August 6<sup>th</sup>).
- MacRae, E. A., N. Lallu, A. N. Searle and J. H. Bowen. 1989. Changes in the softening and composition of kiwifruit *Actinidia deliciosa* affected by maturity at harvest and postharvest treatments. *J. Sci. Food Agric.* 49:413-43.

- Maguire, K.M., R. Spinelli and B. Nicolai. 2007. Within-vine variation in maturity parameters and storage potential of 'Hort 16A' (Zespri Gold) kiwifruit grown in Italy. *Acta Hort.* 753:317-324.
- Marsh, K., S. Attanayake, S. Walker, A. Gunson, H. Boldingh, and E. MacRae. 2004. Acidity and taste in kiwifruit. *Postharvest Biol. and Technol.* 32:159-168.
- McGhie, T.K., and G. D. Ainge. 2002. Color in fruit of the genus *Actinidia*: Carotenoid and chlorophyll compositions. *J. Agric. Food Chem* 50:117-121.
- Mills, T., H. Boldingh, P. Blattmann, S. Green, and J. Meekings. 2008. Nitrogen application rate and the concentration of other macronutrients in the fruit and leaves of gold kiwifruit. *J. Plant Nutr.* 31:1656-1675.
- Mitchell, G.F. 1994. Composition, maturity, and quality, p 94-98. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling*. ANR Publ: Oakland,CA.
- Nardozza, S., H.L. Boldingh, A.C. Richardson, G. Costa, H. Marsh, E.A. MacRae and M.J. Clearwater. 2010a. Variation in carbon content and size in developing fruit of *Actinidia deliciosa* genotypes. *Functional Plant Biology* 37:545-554.
- Nardozza, S., IC. Hallett, R. McCartney, A. C. Richardson, E.A. MacRae, G. Costa and M.J. Clearwater. 2011. Is fruit anatomy involved in variation in fruit starch concentration between *Actinidia deliciosa* genotypes. *Functional Plant Biology* 38: 63-74.
- Nardozza, S., J. Gamble, L.G. Axten, M.W. Wohlers, M.J. Clearwater, J. Feng, and F.R. Harker. 2010b. Dry matter content and fruit size affect flavor and texture of novel *Actinidia deliciosa* genotypes. *J. Sci. Food. Agric.* 91: 742-748.
- National Cotton Council. 2010. Cotton Costs and Returns: United States. National Cotton Council of America. Available: <http://www.cotton.org/econ/cropinfo/costsreturns/usa.cfm> (2010, August 6<sup>th</sup>).
- Nishiyama, I. 2007. Fruits of the *Actinidia* genus. *Adv. in Food Nutr. Res.* 52:293-324.
- Norton, M. V. 1994. Site selection and vineyard development, p 18-20. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling*. ANR Publ: Oakland,CA.
- Paterson, V. J., E. A. MacRae, and H. Young. 1991. Relationships between sensory properties and chemical composition of kiwifruit (*Actinidia deliciosa*). *J. Sci. Food Agric.* 57:235-251.

- Patterson, K., J. Burdon and N. Lallu. 2003. Hort 16A Kiwifruit: Progress and issues with commercialisation. Acta. Hort. 610.
- Reil, W. O. 1994. Vineyard planning, design, and planting, p 25-27 In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). Kiwifruit Growing and Handling. ANR Publ: Oakland,CA.
- Retamales, J., T. Cooper, and J. Montealegre. 1997. Effects of curing and cooling regime on ethylene production and storage behavior of kiwifruit. Acta. Hort. 2:567-571.
- Rossiter, K. L., H. Young, S. B. Walker, and M. Miller. 2000. The effects of sugars and acids on consumer acceptability of kiwifruit. J. Sensory Studies 15:241-250.
- Salinero, M.C., P. Vela, and M.J. Sainz. 2009. Phenological growth stages of kiwifruit *Actinidia deliciosa* 'Hayward'. Scientia Hort. 121:27-31.
- Wall, C. P. 2006. Determining a maturity index and the effect of chilling requirements, and cytokinin applications on three new kiwi cultivars. Auburn University, Auburn, Alabama, Masters Thesis.
- Wall, C., W. Dozier, R. C. Ebel, B. Wilkins, F. Woods, and W. Foshee III. 2008. Vegetative and floral chilling requirements of four new kiwi cultivars of *Actinidia chinensis* and *A. deliciosa*. Hort. Sci. 43:644-647.
- Wen-Hsin, C. and J.F. Liu. 2009. Effects of kiwifruit consumption on serum lipid profiles and antioxidative status in hyperlipidemic subjects. Intl. J. of Food Sci. and Nutr. 1-8.

## CHAPTER II

### The Effects of Fruit Size on Storage Life and Fruit Quality Attributes of Three Varieties of *Actinidia chinensis*

This research focused on the effects of fruit size on postharvest storage life and fruit quality of *Actinidia chinensis* ‘AU Golden Dragon’, ‘AU Golden Sunshine’ and ‘Hort 16A’. Kiwifruit were harvested and sized on August 16, September 16, and October 12, 2010 for ‘AU Golden Dragon’, ‘AU Golden Sunshine’ and ‘Hort 16A’ respectively. Three different marketable sizes (small, medium, and large) were used for this study. The fruit quality of ten fruit per size category was assessed initially and remaining fruit was placed in cold storage. Fruit quality of ten fruit per size category was assessed every 14 days for the duration of the study. As expected, the soluble solids content (SS), SS:titratable acidity ratio (TA), and color development (internal and external) increased for all sizes while the fruit firmness and TA decreased in response to the length of time in cold storage. The % dry weight (% DW) of ‘AU Golden Dragon’ and ‘Hort 16A’ was not affected by fruit size and remained stable in cold storage. Small ‘AU Golden Sunshine’ fruit had higher % DW than medium and large fruit, and % DW increased linearly in cold storage. Fruit quality attributes indicated that small fruit was less mature compared to medium and large fruit at harvest. Fruit firmness tended to be reduced in

**medium and large ‘Hort 16A’ and ‘AU Golden Sunshine’ fruit in the latter weeks of cold storage; indicating that small fruit had a greater potential storage life.**

**Additionally, medium and large fruit had lower TA, greater SS and SS:TA, and more internal color development than small ‘AU Golden Sunshine’ fruit in the latter weeks. Though effects of fruit size on fruit quality attributes varied between the cultivars in this study, small *A. chinensis* fruit appear to possess greater storage life potential compared to larger fruit.**

Golden kiwifruit production in New Zealand is a 160 million dollar industry that accounts for 17 – 18 % of New Zealand’s total kiwifruit exportation (Nishayama, 2007). *Actinidia chinensis* ‘Hort 16A’, marketed as Zespri Gold, is the primary golden kiwifruit cultivar currently produced in New Zealand. *A. chinensis* ‘AU Golden Dragon’ and *A. chinensis* ‘AU Golden Sunshine’ are new kiwifruit cultivars developed by Auburn University and the Institute of Fruit and Tea, Hubei province, P.R. China. These two new cultivars of golden kiwifruit have been evaluated since 1995 at the Chilton Research and Extension Center, Clanton, Alabama, and appear to be well adapted to the climate of the southeastern United States.

Taste is one of the most important factors when determining the acceptability of kiwifruit (Jaeger et al., 2011). Several studies to assess consumer preference of kiwifruit quality attributes have determined that % dry weight (% DW) and percent soluble solids (% SS) are key quality measurements to determine consumer preference. Consumers typically prefer kiwifruit with higher % DW and higher % SS (Burdon et al., 2004; Crisosto and Crisosto, 2001; Harker, 2004; Harker et al., 2009; Jaeger et al., 2011). In

addition, % DW content was determined to be the most important determinant of purchase likelihood/choice probability of both *A. deliciosa* 'Hayward and *A. chinensis* 'Hort 16A' (Jaeger et al., 2011). In a comprehensive study by Harker et al. (2009), consumers tended to prefer the green fleshed 'Hayward' when the SS content was above 16 % and the % DW was above 17 %. In the same study, 'Hort 16A' was preferred when the SS content was at or above 14 %, and the % DW was above 16% (Harker et al., 2009). Consumers have stated that 'Hort 16A' has a flavor that is tropical, sweet, like blackcurrant, aromatic melon, candy floss, and fruit candy (Harker et al., 2009; Harker et al., 2007; Jaeger et al., 2003). Fully ripened fruit produce volatile and nonvolatile compounds, increasing the flavor and aroma that are pleasing to consumers (Harker et al., 2009; Kader, 2008). In less ripe fruit the consumer preference is driven by the % SS and % TA. As the fruit matures and the aroma and flavor develop, the acceptance of lower % SS fruit becomes evident (Harker et al., 2009)

There has been research that shows a potential link between storage life and size of kiwifruit, as well as sugar development and fruit size. Within the same genotype, the % DW was reduced in larger fruit compared to smaller fruit of *A. deliciosa* (Nardozza et al., 2010a; Nardozza et al., 2010b). Nardozza et al. (2010a) suggested that stored carbohydrate concentrations were diluted in the larger fruit, as larger fruit had a greater proportion of large cells. It was also determined that larger fruit tend to have more cells (Nardozza et al., 2010a) and that high % DW fruit have a lower proportion of large cells (Nardozza et al., 2011). Larger *A. deliciosa* fruit were also firmer and had a lower % SS compared to the smaller fruit (Nardozza et al., 2010b). A study of *A. deliciosa* 'Hayward' kiwifruit demonstrated that the larger the fruit, or higher the fresh weight, the less the



fruit softened over the length of storage (Crisosto et al., 1999). This study indicated that larger ‘Hayward’ kiwifruit have a potential to store longer on a commercial level (Crisosto et al., 1999).

Proper storage of the fruit is essential in order to get the maximum revenue from harvested kiwifruit. The length of storage can determine the potential market of a kiwifruit cultivar and the qualities that make a kiwifruit valuable, such as fruit firmness and % SS. As the production of golden kiwifruit continues to expand, the effect of fruit size on fruit quality and storage life is important to know for better world distribution (Schultz and McNeil, 1994). Larger ‘Hayward’ kiwifruit were observed to have greater storage potential than smaller fruit due to greater firmness (Crisosto et al., 1999). The objective of this study is to determine whether fruit size affects storage life and fruit quality attributes of three golden kiwifruit (*A. chinensis*) cultivars in cold storage.

### **Materials and Methods**

Three cultivars of *Actinidia chinensis*, ‘AU Golden Dragon’, ‘AU Golden Sunshine’ and ‘Hort 16A’, were harvested on August 16<sup>th</sup>, September 16<sup>th</sup>, and October 12<sup>th</sup> 2010, respectively, from the Chilton Research and Extension Center, Clanton, AL. Kiwifruit were monitored weekly for hue angle, % SS, and % DM and harvested when the hue angle was below 108°. Kiwifruit were separated according to weight and placed into commercial kiwifruit shipping trays with appropriate tray inserts. The kiwifruit sizes in the study were represented as large, medium and small. The sizes for ‘AU Golden Dragon’ were 27/28 (98-109g) for large, 33 (82-87g) for medium and 39 (71-76g) for small. The sizes for ‘AU Golden Sunshine’ were 30 (88-97g) for large, 36 (77-81g) for

medium and 39 (71-76g) for small. The sizes for 'Hort 16A' were 33 (82-87g) for large, 36 (77-81g) for medium and 39 (71-76g) for small. Size categories correspond to a specific weight in grams of harvested kiwifruit. Kiwifruit trays are labeled based on the number of fruit for a certain size that will fit in a commercial kiwifruit tray, for example a number 30 tray holds 30 kiwifruit sized 30 (88 - 97g). Six trays of each size were then transported to Auburn University, Auburn AL, to implement the study. Ten fruit from each size category were kept at room temperature (20 °C) for 24 hours prior to initial fruit quality measurements. Remaining fruit in trays were placed in cold storage room set at 0 °C and 95% relative humidity. Two data loggers were placed in the cooler to monitor the temperature and the relative humidity. The temperature was maintained at  $1 \pm 0.83$  °C and relative humidity at  $91 \pm 4$  %. For the remainder of the study, ten fruit from each size category were randomly selected every 13 days and placed in trays on the laboratory bench top at room temperature for 24 hours prior to the analysis. Each individual fruit was considered a replicate.

### **Fruit quality analysis**

In 2010, on August 17<sup>th</sup> for 'AU Golden Dragon', September 17<sup>th</sup> for 'AU Golden Sunshine', and October 12<sup>th</sup> for 'Hort 16A' and then on 14 day intervals, fruit quality was determined for ten individual fruit from each size category. The following data was collected for each fruit: weight, length, width, percent soluble solids (SS), internal color (IC), and external color (EC), firmness (kg), percent dry weight (% DW), titratable acidity (TA) and the ratio of SS:TA. Fruit analysis continued until the fruit reached a firmness that was less than 0.46 kg of pressure or until the fruit was determined to be

unsalable due to injury. Less than 0.46 kg of firmness was used as a termination point because according to Zespri™ the optimum eating pressure is between 0.46 kg - 1 kg pressure (Patterson et al., 2003; Zespri™, 2010). Two outer color measurements and one internal color measurement were taken using a Minolta CM-2002 spectrophotometer (Minolta, Tokyo, Japan). Internal color was determined by cutting a 1 mm slice from the shoulder of the kiwifruit, and measuring the hue angle with the colorimeter. Colors on a color wheel can be represented by degrees around the 360 degree wheel where red purple is represented at 0 degrees, yellow at 90 degrees, blue green at 180 degrees, and blue at 270 degrees (McGuire, 1992). Degree readings make color readings easier to see and less likely to misinterpret when compared to other measurements of color (McGuire, 1992). Firmness was then taken on the same cut area on the shoulder where the internal color measurement was taken. Firmness was measured with a bench top penetrometer using a 8-mm (5/16 inch) probe (Model FT 327, McCormick Fruit Tech, Yakima, Washington). Firmness was measured in kg of force needed to insert the 8 mm probe 1 cm into the flesh of the fruit.

A 10 mm section was cut from both the flower and the vine end of the fruit to measure the % SS content. Percent SS content for both fruit ends were determined using a Leica Mark II Abbe refractometer (Leica Inc., Buffalo, NY, USA). The average of the top and bottom SS measurements were used to determine fruit SS content. The remainder of the kiwifruit was cut in half and a 3 mm slice was taken from the middle section of both halves. Both slices were weighed and then dried in a food dehydrator (Excalibur products, Sacramento, California) at 62.7 °C for 24 hours. They were then re-weighed to determine the percent dry weight ( $DW/FW \times 100$ ).

Twenty-five g of the remaining kiwifruit samples were added to 100 ml of HPLC water from a Millipore Direct-Q5 filter system (Millipore Corp., Bedford, MA). This was blended until all the kiwifruit was in a slurry consistency. This slurry was kept in motion with the help of stir plates until ready to be poured into test tubes. Twenty-five grams of the slurry was placed in test tubes and spun in a centrifuge (Model J2-21; Beckman Centrifuge, San Antonio, TX) for 15 min at 15000g<sub>n</sub> to separate out the solids and extract the supernatant. The supernatant was poured through grade 50 cheesecloth into 50 ml beakers. Five ml of supernatant was added to 25 ml of HPLC water for a final volume of 30 ml. TA was measured using an automated titrimer (Metrohm Titrino Model 751 and Metrohm Sample Changer; Metrohm Corp., Herisau, Switzerland) and associated software (Brinkmann Titrino Workcell 4.4 Software; Brinkmann Corp., Westbury, NY, USA). The automatic titrimer was housed in a Fisher Scientific refrigerated chromatography chamber maintained at 10 °C (Model Isotemp Laboratory Refrigerator; Fisher Scientific, Raleigh, NC, USA). A 0.1 M solution of NaOH was titrated to the endpoint of pH 8.1 and the results were expressed in citric acid equivalent using the formula: [(mL NaOH × 0.1N × 0.064 meq·g<sup>-1</sup> of juice) × 100].

Data were analyzed using Proc Mix and Proc Glimmix of Statistical Analysis Systems (Version 9.1; S.A.S. Inc., Cary NC), and least squared means separation using Tukey's least significant difference at  $\alpha = 0.05$ .

## Results

### **‘AU Golden Dragon’**

There were interactions of the storage duration and size for specific weeks, particularly at day 0 (harvest) (Table 2.1). Size did appear to affect the SS:TA content in the fruit, with small fruit having a lower SS:TA than the medium and large fruit (Table 2.2). This was primarily due to a lower SS content in small fruit at harvest (Table 2.1). Fruit firmness and TA decreased in a linear fashion in response to length of time in cold storage, but there were no differences due to fruit size (Table 2.2). The SS:TA ratio increased linearly in response to time in cold storage (Table 2.2).

The significant trends in the interactions of the main effects of storage duration and size are shown in Table 2.1. The SS content of fruit increased linearly over the length of time in cold storage. At harvest (Week 0), large and medium fruit had higher SS content than small fruit. There were slight differences due to size in weeks 12 and 14. However, chilling injury was observed in a low percentage of ‘AU Golden Dragon’ fruit in week 10 of this study. By week 14, chilling injury was present in all of the fruit, regardless of size. For this reason, the study was terminated at 14 weeks, even though the fruit firmness never decreased to the 0.46 kg threshold.

The % DW was consistent throughout the duration of the study with a mean of  $16.22 \pm 2.79$ . The % DW was measured incorrectly on Week 0 and reported as missing data. The external and internal color development responded in a similar fashion. Color development increased linearly in response to cold storage, as determined by the lower hue angle. At harvest (Week 0), the medium and large sized fruit exhibited a darker

(brown) external color compared to the small fruit. Similarly, the internal color was a darker shade of yellow at harvest in large fruit compared to small fruit (Table 2.1).

### **‘AU Golden Sunshine’**

Though variable throughout the data collection weeks, interactions of the main effects of storage duration and size were significant for some of the fruit quality attributes (Table 2.3). Size appeared to affect fruit firmness in weeks 0, 4, and 10, but the results were variable. However, the smaller sized fruit were firmer in weeks 12 and 14 when compared to the medium and large fruit, indicating that the smaller fruit had greater storage potential. There were storage duration  $\times$  size interactions in weeks 8, 10, 12, and 14 for SS content. Though in week 10 the smaller fruit had a higher SS content compared to the larger sized fruit, in weeks 8, 12, and 14 the small fruit had a lower SS content than the medium and large fruit. There were storage duration  $\times$  size interactions for internal color in weeks 0, 8, 12, and 14 that indicated that the medium and large fruit were a darker yellow color compared to the small fruit. In weeks 0, 8, 10, and 14 there were interactions of the main effects of storage duration and size for TA and SS:TA ratio. With the exception of week 10, the TA was greater and the SS:TA ratio was lower in small fruit compared to medium and large fruit. Indicative of maturing fruit and regardless of size, the firmness and TA decreased, while the SS content, SS:TA, and color development increased linearly due to length of time in cold storage (Table 2.3).

Interestingly, the % DW increased slightly in response to weeks in cold storage (Table 2.4). There was an effect of fruit size on % DW in ‘AU Golden Sunshine’ fruit. Small fruit had a slightly higher % DW (19.3%) compared to medium (18.8%) and large

(18.8%) fruit. There were no interactions of the main effects of storage duration and size for % DW (Table 2.4).

### **‘Hort 16A’**

The interactions of the main effects of storage duration and size affected fruit firmness in weeks 0, 2, 10, and 14. Small fruit tended to be firmer compared to medium and large fruit, as demonstrated in weeks 0, 10, and 14 (Table 2.5). Though no trend could be established, there were interactions of the main effects of week and size in weeks 6 and 8 for SS indicating that medium and large fruit had more SS than small fruit in week 6, and small and large fruit had more SS than medium sized fruit in week 8. The % DW remained stable in cold storage with a mean of  $21.44 \pm 1.03$ . There were no interactions of the main effects of storage duration and size for external color development (Table 2.5).

A main effect of fruit size on TA was observed, with large and small fruit having greater TA than medium fruit (Table 2.6). There were no interactions of the main effects of storage duration and size for TA, internal color, and SS:TA ratio. As previously observed with ‘AU Golden Dragon’ and ‘AU Golden Sunshine’, fruit firmness and TA decreased, while the SS content, SS:TA ratio, and color development increased linearly in response to length of time in cold storage (Tables 2.5, 2.6).

## **Discussion**

The influence of fruit size on fruit quality attributes and storage life was slightly variable for the three cultivars. Fruit firmness is typically the primary indicator of

storage life potential. Fruit size did not consistently affect fruit firmness for the entire duration of this study. However, there were several interactions of the main effects of storage duration and size in the latter weeks of cold storage in which the smaller fruit were firmer than medium and large fruit for 'AU Golden Sunshine' and 'Hort 16A' that indicated that smaller fruit have greater storage life potential. This is in contrast to previous findings with *A. deliciosa* 'Hayward', in which the larger sized fruit reportedly have greater potential for a long storage life (Crisosto et al., 1999).

There were several fruit quality attributes suggesting that the small fruit were less mature at harvest than the larger fruit. Greater external and internal color development, along with higher SS in medium and large 'AU Golden Dragon' fruit indicated that larger fruit were more mature at harvest than the small fruit. Similarly, smaller 'AU Golden Sunshine' fruit were firmer, had less internal color development, greater TA, and a lower SS:TA at harvest. Smaller fruit from 'Hort 16A' were firmer at harvest as well. Though fruit quality attributes were variable for many of the weeks in cold storage, the level of fruit maturity at harvest could have contributed to the greater firmness of small 'AU Golden Sunshine' and 'Hort 16A' fruit in the later weeks of cold storage. Differences in fruit maturity could be attributed to variance of bloom on kiwifruit vines, thus a difference in age of fruit on a vine. *A. chinensis* flowering typically occurs over an 11 day period, and there appears to be a 6-12 day effective pollination period (Cheng et al., 2006). It is plausible that the smaller fruit is a result of flowers that were pollinated later than those of the larger fruit. Kiwifruit are typically harvested at a single time leading to a range of maturity at harvest (Maguire et al., 2007). Kiwifruit maturity can vary due to the location of kiwifruit within canopies. 'Hort 16A' harvested from the inner canopy was



determined to be less mature than outer canopy fruit, as inner canopy fruit had lower internal color and less % SS content than outer canopy fruit (Maguire et al., 2007).

The effect of fruit size on storage life of 'AU Golden Dragon' could not be accurately determined in this study. 'AU Golden Dragon' fruit suffered chilling injury by week 10 in cold storage. Chilling injury, or low temperature breakdown, symptoms were evident as water soaked tissue within the pericarp (flesh) (Lallu, 1997). Less mature kiwifruit have an increased risk of chilling injury (Maguire et al., 2005). There is a greater potential for chilling injury to occur in cold storage (0 °C) with a % SS content below 6.3% (Lallu, 1997; Crisosto and Crisosto, 2001). Canopy placement also potentially plays a role in chilling injury. Immature 'Hort 16A' kiwifruit harvested from the inner canopy have been shown to have a greater chilling injury potential when compared to kiwifruit harvested from the outer canopy (Maguire et al., 2007). Fruit SS content and maturity were likely contributors, as % SS were 6.2, 6.3, and 5.7 for the large, medium, and small 'AU Golden Dragon' fruit respectively, at harvest.

Regardless of size and fruit maturity, fruit firmness and TA decreased, while SS, SS:TA and color development increased linearly due to length of time in cold storage for all three cultivars. The % DW of 'AU Golden Dragon' and 'Hort 16A' was not affected by fruit size and remained constant in cold storage. Interestingly, % DW in 'AU Golden Sunshine' fruit increased linearly (though slightly) and was affected by fruit size. Possibly the respiration within the 'AU Golden Sunshine' cultivar was slightly higher than the other two cultivars causing the results seen in the differences of % DW trends among the three cultivars (Heyes et al., 2009). Small fruit had higher % DW than medium and large fruit. Nardozza et al. (2010a; 2010b) also reported that smaller fruit

had greater % DW in studies with genotypes of *A. deliciosa*. In contrast, the % DW was reportedly higher in larger fruit from *A. deliciosa* ‘Hayward’ (Crisosto et al., 1999).

‘AU Golden Dragon’ small fruit had a lower SS:TA ratio than medium and large fruit. This appears to be primarily due to a lower SS content in small fruit at harvest. Fruit size did not affect SS or SS:TA ratio in ‘Hort 16A’ fruit. However, the green-fleshed ‘Hayward’ kiwifruit as well as other green-fleshed genotypes were reported to have higher SS in larger kiwifruit (Crisosto et al., 1999; Nardozza et al., 2010a; Nardozza et al., 2010b). Though not evident in all weeks, medium and large ‘AU Golden Sunshine’ fruit tended to have greater SS than small fruit in the latter weeks of cold storage. Additionally, medium and large fruit had lower TA, greater SS:TA ratio, and more internal color development than small ‘AU Golden Sunshine’ fruit in the latter weeks. Hence, in addition to increased fruit softening (reduced fruit firmness) observed in larger fruit, these results support the conclusion that medium and large ‘AU Golden Sunshine’ fruit were more mature after 14 weeks in cold storage than smaller fruit.

The results of this study indicate that smaller *A. chinensis* fruit could be stored longer than larger fruit. However, effects of fruit size on fruit quality attributes in cold storage varied between the cultivars in this study. Depending on the fruit quality attribute and cultivar, our results are in support of and/or in contrast to previous research (Crisosto et al., 1999; Nardozza et al., 2010a; Nardozza et al., 2010b). In the present study, small fruit appeared to be less mature at harvest, which likely influenced the storage life as well as the quality attributes that consumers prefer. In other words, large fruit may not have ripened faster in cold storage; large fruit may have been more mature at harvest and ripened at the same rate. As previously mentioned, small fruit used in this study could

have resulted from flowers that were pollinated later than those that resulted in larger fruit. Also, the location of fruit within the canopy can affect fruit size and maturity (Maguire et al., 2007; Snelgar et al., 1998; Snelgar et al., 2007). Pollination and subsequent seed development is known to affect fruit quality and may have played a role in fruit size effects (Patterson et al., 2003). With the maturity stage being an important factor influencing flavor and quality, future research is needed to determine the cause of variation in fruit size and the subsequent influence on fruit quality and storage life (Kader, 2008).

## Literature Cited

- Burdon, J., D. McLeod, N. Lallu, J. Gamble, M. Petley, and A. Gunson. 2004. Consumer evaluation of 'Hayward' kiwifruit of different at harvest dry matter contents. *Postharvest Biol. and Technol.* 34:245-255.
- Cheng, C.H., A.G. Seal, S.J. Murphy and R.G. Lowe. 2006. Variability and inheritance of flowering time and duration in *Actinidia chinensis* kiwifruit. *Euphytica*. 147:395-402.
- Crisosto, C.H. and G. M. Crisosto. 2001. Understanding consumer acceptance of early harvested 'Hayward' kiwifruit. *Postharvest Biol. and Technol.* 22:205-213.
- Crisosto, C.H., D. Garner, and K. Saez. 1999. Kiwifruit size influences softening rate during storage. *California Agri.* 53:29-31.
- Harker, F.R. 2004. Consumer evaluation of taste and flavor: Zespri Gold and Zespri Green. *Hort Research.* 166: 5-9.
- Harker, F.R., B.T. Carr, M. Lenjo, E.A. MacRae, W.V. Wismer, K.B. Marsh, M. Williams, A. White, C.M. Lund, S.B. Walker, F.A. Gunson and R.B. Pereira. 2009. Consumer liking for kiwifruit flavor: A meta-analysis of five studies on fruit quality. *J. Food. Qual. Pref.* 20:30-41.
- Heyes, J.A., D.J. Tanner and A.R. East. 2010. Kiwifruit respiration rates, storage temperatures and harvest maturity. *Acta. Hort.* 880:167-174.
- Jaeger, S.R., R. Harker, C.M. Triggs, A. Gunson, R.L. Campbell, R. Jackman, and C. Requejo-Jackman. 2011. Determining consumer purchase intentions: The importance of dry matter, size, and price of kiwifruit. *J. of Food Sci.* 76:177-184.
- Kader, A.A. 2008. Perspective flavor quality of fruits and vegetables. *J. Sci. Food Agric.* 88: 1863-1868.
- Lallu, N. 1997. Low temperature breakdown in kiwifruit. *Acta. Hort.* 2:579-585.
- Maguire, K.M., N. Amos, and D. Kelly. 2005. Influence of storage temperature and at-harvest maturity on incidence of chill-related disorders in 'Hort16A' kiwifruit. *Acta Hort.* 687:57-61.

- Maguire, K.M., R. Spinelli and B. Nicolai. 2007. Within-vine variation in maturity parameters and storage potential of 'Hort 16A' (Zespri Gold) kiwifruit grown in Italy. *Acta Hort.* 753:317-324.
- McGuire, R.G. 1992. Reporting of the objective color measurements. *Hortscience* 27:1254-1255.
- Nardozza, S., H.L. Boldingh, A.C. Richardson, G. Costa, H. Marsh, E.A. MacRae and M.J. Clearwater. 2010a. Variation in carbon content and size in developing fruit of *Actinidia deliciosa* genotypes. *Functional Plant Biology* 37:545-554.
- Nardozza, S., I.C. Hallett, R. McCartney, A. C. Richardson, E.A. MacRae, G. Costa and M.J. Clearwater. 2011. Is fruit anatomy involved in variation in fruit starch concentration between *Actinidia deliciosa* genotypes. *Functional Plant Biology* 38: 63-74.
- Nardozza, S., J. Gamble, L.G. Axten, M.W. Wohlers, M.J. Clearwater, J. Feng, and F.R. Harker. 2010b. Dry matter content and fruit size affect flavor and texture of novel *Actinidia deliciosa* genotypes. *J. Sci. Food. Agric.* 91: 742-748.
- Nishiyama, I. 2007. Fruits of the *Actinidia* genus. *Adv. in Food Nutr. Res.* 52:293-324.
- Patterson, K., J. Burdon and N. Lallu. 2003. Hort 16A kiwifruit: Progress and issues with commercialisation. *Acta Hort.* 610.
- Schultz, T. and E. McNeil. 1994. Marketing, p 3-5. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling*. ANR Publ: Oakland,CA.
- Snelgar, W.P., A.J. Hall, A.C. Richardson, and M.B. Currie. 2007. Influence of temperature on between season variation in dry matter content of 'Hayward' kiwifruit. *Acta Hort.* 753: 383-386.
- Snelgar, W.P., G. Hopkirk, R.J. Seelye, P.J. Martin and P.J. Manson. 1998. Relationship between canopy density and fruit quality of kiwifruit. *New Zealand J. of Crop and Hort. Sci.* 26: 223-232.
- Snelgar, W.P., P.E.H. Minchin and P. Blattmann. 2005. Altering growth and maturation of *Actinidia chinensis* 'Hort 16A' fruit by heating individual berries. *J. Hort Sci. Biotech.* 80:779-785.
- Zespri. 2010. Storage and handling of kiwifruit. New Tech Web inc. 6<sup>th</sup> August 2010. <<http://www.zesprikiwi.com/storage.htm>>

## Appendix A: Tables

Table 2.1: Effect of fruit size and cold storage duration on ‘AU Golden Dragon’ kiwifruit % SS, external and internal color.<sup>z</sup>

Attribute <sup>y</sup>	Size <sup>x</sup>	Weeks								Sign <sup>w</sup>
		0	2	4	6	8	10	12	14	
SS (%)	LG	6.2a <sup>y</sup>	8.5ns	9.8ns	10.9ns	11.9ns	12.7ns	12.8a	13.5a	L*** <sup>y</sup>
	MD	6.3a	8.6	9.8	11.2	11.5	12.4	12.0b	13.0ab	L***
	SM	5.7b	8.3	9.6	10.9	11.8	12.3	12.6a	12.6b	L***
EC (Hue°)	LG	79.1b	79.4ns	76.1ns	81.2ns	83.6ns	69.4ns	70.6ns	71.7ns	L***
	MD	77.3b	82.5	75.9	80.3	81.9	74.0	75.6	72.0	L***
	SM	83.8a	78.3	79.0	80.5	81.0	66.4	69.3	69.2	L***
IC (Hue°)	LG	103.0b	103.6ns	103.9ns	102.5ns	101.7ns	102.4ns	101ns	100.2ns	L***
	MD	104.2a	103.6	104.1	103.6	102.2	102.2	101.7	99.8	L***
	SM	106.0a	104.1	103.6	102.0	103.8	101.1	102.2	101.5	L***

<sup>z</sup>The fruit size × week of cold storage interaction was significant at  $\alpha = 0.05$  for all fruit quality attributes.

<sup>y</sup>SS= Soluble solids, EC= External color, IC= Internal color.

<sup>x</sup>LG= Large, MD= Medium, SM= Small.

<sup>w</sup>Significant linear (L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*). Sign = Significance.

<sup>y</sup>Least squared means comparison among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$ , ns=not significant.

Table 2.2: Effect of fruit size and cold storage duration on ‘AU Golden Dragon’ kiwifruit firmness, the soluble solids titratable acidity ratio (SS:TA), and TA.

Weeks	Firmness (kg) <sup>z</sup>	SS:TA <sup>y</sup>	Size	SS:TA	TA <sup>x</sup> (% citric)
0	5.3	3.3	Large	7.0a <sup>w</sup>	1.6
2	5.6	4.7	Medium	7.0a	1.5
4	4.7	5.5	Small	6.7b	1.5
6	4.6	6.2			1.5
8	3.4	6.8			1.5
10	3.4	7.8			1.4
12	2.5	9.6			1.3
14	1.6	11.5			1.2
Sign. <sup>v</sup>	L***	L***			L***

<sup>z</sup>Only the cold storage duration main effect was significant at  $\alpha = 0.05$  for fruit firmness.

<sup>y</sup>Only the fruit size and cold storage duration main effects were significant at  $\alpha = 0.05$  for Soluble solids Titratable acidity ratio (SS:TA).

<sup>x</sup>Only the cold storage duration main effect was significant at  $\alpha = 0.05$  for titratable acidity.

<sup>w</sup>Least squared means comparisons among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$ .

<sup>v</sup>Significant linear(L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*), Sign. = Significance.

Table 2.3. Effect of fruit size and cold storage duration on ‘AU Golden Sunshine’ kiwifruit firmness, SS, external and internal color, TA, and SS:TA.<sup>z</sup>

Attribute <sup>y</sup>	Size <sup>x</sup>	Weeks								Sign. <sup>w</sup>
		0	2	4	6	8	10	12	14	
Firm (kg)	LG	5.0b <sup>v</sup>	3.9ns	1.9b	1.8ns	0.6ns	0.9a	0.7b	0.3b	L***
	MD	5.5b	4.0	2.7a	2.5	1.0	0.7a	0.7b	0.5b	L***
	SM	6.6a	4.2	1.7b	1.8	1.5	0.5b	1.7a	0.8a	L***
SS (%)	LG	9.8ns	12.7ns	13.7ns	13.7ns	15.1a	15.1b	15.7a	15.6b	L***
	MD	9.0	11.6	13.4	13.2	15.2a	15.1b	14.8a	17.5a	L***
	SM	8.2	12.2	14.9	14.0	13.6b	16.1a	13.8b	14.5c	L***
EC (Hue°)	LG	75.5a	75.0ns	74.7ns	73.1ns	67.8ns	65.6ns	63.4ns	67.8b	L***
	MD	75.1a	76.6	76.4	70.5	69.7	65.3	61.9	64.9b	L***
	SM	71.4b	74.4	76.2	70.5	69.45	63.5	63.9	71.3a	L***
IC (Hue°)	LG	99.5b	100.7ns	100.1ns	100.1ns	99.5b	100.2ns	99.2b	96.8b	L***
	MD	101.0b	101.1	101.3	101.3	98.7b	98.8	96.8b	97.5b	L***
	SM	104.1a	101.9	100.1	100.1	103.6a	97.3	103.1a	99.5a	L***
TA (%)	LG	1.39b	1.4ns	1.3ns	1.3ns	1.3b	1.3a	1.2ns	1.2c	L***
	MD	1.43b	1.4	1.4	1.4	1.3b	1.2b	1.2	1.3b	L***
	SM	1.7a	1.5	1.4	1.4	1.5a	1.2b	1.3	1.4a	L***
SS:TA	LG	7.2a	9.2ns	10.2ns	10.2ns	11.5a	11.7b	12.9ns	12.9a	L***
	MD	5.4b	8.0	9.4	9.4	12.1a	12.5b	12.9	13.2a	L***
	SM	4.9b	8.2	11.0	9.8	9.4b	14.0a	10.9	10.2b	L***

<sup>z</sup>The fruit size × week of cold storage interaction was significant at  $\alpha = 0.05$  for all fruit quality attributes.

<sup>y</sup>Firm= Firmness, SS= Soluble solids, EC= External color, IC= Internal color, TA= Titratable Acidity, SS:TA= Soluble solids Titratable acidity ratio.

<sup>x</sup>LG= Large, MD= Medium, SM= Small.

<sup>w</sup>Significant linear (L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*). Sign. = Significance.

<sup>v</sup>Least squared means comparison among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$ , ns=not significant.



Table 2.4. Effect of fruit size and cold storage duration on ‘AU Golden Sunshine’ kiwifruit percent dry weight (% DW).

Weeks	DW <sup>z</sup> (%)	Size	DW (%)
0	18.6	Large	18.8a <sup>y</sup>
2	19.2	Medium	18.8a
4	18.9	Small	19.3b
6	18.5		
8	19.0		
10	19.1		
12	19.2		
14	19.2		
Sign. <sup>x</sup>	L***		

<sup>z</sup>Only the cold storage duration and fruit size main effects were significant at  $\alpha = 0.05$  for percent dry weight (% DW).

<sup>y</sup>Least squared means comparisons among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$ .

<sup>x</sup>Significant linear(L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*), Sign. = Significance.

Table 2.5: Effect of fruit size and cold storage duration on ‘Hort 16A’ kiwifruit firmness, soluble solids (SS), and external color.<sup>z</sup>

Attribute <sup>y</sup>	Size <sup>x</sup>	Weeks								Sign. <sup>w</sup>
		0	2	4	6	8	10	12	14	
Firm (kg)	LG	6.0b <sup>v</sup>	6.0a	4.8ns	2.2ns	1.3ns	0.6b	0.5ns	0.3b	L***
	MD	6.8a	6.3a	5.0	2.4	1.7	0.8b	0.6	0.4b	L***
	SM	6.9a	5.3b	4.6	2.3	1.3	1.0a	0.5	0.6a	L***
SS (%)	LG	12.5ns	14.8ns	14.7ns	17.7a	18.1a	17.4ns	17.7ns	17.3ns	L***
	MD	12.4	14.4	14.9	16.8a	16.7b	17.5	17.8	17.5	L***
	SM	11.8	14.8	15.3	16.3b	17.7a	17.9	17.8	17.2	L***
EC (Hue°)	LG	76.1ns	73.1ns	70.2ns	70.2ns	70.2ns	68.9ns	68.3b	67.7ns	L***
	MD	76.9	73.4	71.1	70.5	68.6	67.4	69.8b	66.3	L***
	SM	77.6	73.9	71.7	71.3	70.6	68.9	72.1a	67.7	L***

<sup>z</sup>The fruit size × week of cold storage interaction was significant at  $\alpha = 0.05$  for all fruit quality attributes.

<sup>y</sup>Firm= Firmness, SS= Soluble solids, EC= External color.

<sup>x</sup>LG= Large, MD= Medium, SM= Small.

<sup>w</sup>Significant linear (L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*). Sign = Significance

<sup>v</sup>Least squared means comparison among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$ , ns=not significant.

Table 2.6: Effect of fruit size and cold storage duration on ‘Hort 16A’ kiwifruit internal color, titratable acidity (TA), and the ratio of soluble solids to titratable acidity (SS:TA).

Weeks	IC <sup>z</sup> (Hue°)	TA <sup>y</sup> (%Citric)	Size	TA (% Citric)	SS:TA <sup>x</sup>
0	104.9	1.5	Large	1.4a <sup>w</sup>	8.4
2	104.7	1.4	Medium	1.3b	10.8
4	104.9	1.4	Small	1.4a	10.9
6	101.8	1.4			12.4
8	100.7	1.3			13.8
10	101.5	1.2			15.0
12	100.0	1.4			13.2
14	100.5	1.2			14.8
Sign. <sup>v</sup>	L***	L***			L***

<sup>z</sup>Only the cold storage duration main effect was significant at  $\alpha = 0.05$  for fruit internal color.

<sup>y</sup>Only the fruit size and cold storage duration main effects were significant at  $\alpha = 0.05$  for titratable acidity (TA).

<sup>x</sup>Only the cold storage duration main effect was significant at  $\alpha = 0.05$  for soluble solids titratable acidity ratio (SS:TA)

<sup>w</sup>Least squared means comparisons among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$

<sup>v</sup>Significant linear(L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*), Sign= Significance.

### CHAPTER III

#### **The Postharvest Life and Fruit Quality Attributes of *Actinidia chinensis* ‘AU Golden Sunshine’ and ‘Hort 16A’ Grown in Central Alabama**

The objectives of this study were to determine fruit quality and the approximate postharvest storage life of *Actinidia chinensis* ‘AU Golden Sunshine’ and ‘Hort 16A’ kiwifruit grown in Clanton, AL. Kiwifruit were harvested and sized on September 17<sup>th</sup>, and October 13<sup>th</sup> 2010 for ‘AU Golden Sunshine’ and ‘Hort 16A’ respectively, from the Chilton Research and Extension Center, Clanton, AL. Fruit quality of ten fruit was assessed every 14 days for the duration of the study. ‘Hort 16A’ fruit had greater SS content, SS:TA ratio, and % DW compared to ‘AU Golden Sunshine’. There were no differences between the cultivars in fruit firmness. Fruit external color and titratable acidity were similar for the two cultivars. Fruit internal color was often similar for the two cultivars, but ‘AU Golden Sunshine’ fruit tended to be a darker yellow color. Fruit from both cultivars were well above fruit quality standards preferred by consumers. The postharvest life of ‘AU Golden Sunshine’ was similar (14 weeks) to ‘Hort 16A’, which is the current industry standard.

Production of golden kiwifruit has risen from 504,500 tons in the top three kiwi producing countries in 1994 to 1,008,955 tons produced by the same top three countries in 2010 (FAOSTAT, 2010; Schultz and McNeil, 1994). *Actinidia chinensis* ‘Hort 16A’, marketed as Zespri Gold, is the primary golden kiwifruit cultivar currently produced. ‘Hort 16A’ in New Zealand is currently a 160 million dollar industry accounting for 17 – 18 % of New Zealand’s total kiwifruit exportation (Nishayama, 2007). As golden kiwifruit popularity increases, there are opportunities for new cultivars of golden kiwifruit that could extend the seasonal availability. *A. chinensis* ‘AU Golden Sunshine’ is a new kiwifruit variety developed by Auburn University and the Institute of Fruit and Tea, Hubei province, P.R. China. ‘AU Golden Sunshine’ typically has harvest time 3 – 4 weeks earlier than ‘Hort 16A’ in central AL. This new variety of golden kiwifruit, is well adapted to the climate of the southeastern United States, and has been evaluated yearly since 1995 at the Chilton Research and Extension Center, Clanton, Alabama.

When comparing varieties, factors such as length of storage, percent soluble solids (% SS), internal color (for harvest) and percent dry weight (% DW), are factors that can determine the marketability and acceptance of consumers. Percent dry weight and the % SS content of the kiwifruit, which adds to the sweet flavor, is an important factor when comparing cultivars and consumer evaluations of kiwifruit cultivars (Burdon et al., 2004; Jordan et al., 2000). It has been shown that consumers are willing to pay more for kiwifruit with higher % DW (Jaeger et al., 2011). Sensory panels that compared different kiwifruit of different % DW preferred ‘Hayward’ kiwifruit with higher % DW (minimum of 12.5% DW), and ‘Hort 16A’ fruit with % DW above 16% and % SS at or above 14 % (Burdon et al., 2004; Crisosto and Crisosto, 2001; Harker et al., 2009;

Nardozza et al., 2010b). However according to a study in New Zealand, consumers could not tell the difference between fruit with a % DW between 15 and 20% (Burdon et al., 2004).

Percent soluble solids play a role in the intensity of the sweet flavor in a kiwifruit cultivar. 'Hort 16A' is sweeter, with a soluble solid content of 9 – 14% at harvest, when compared to the green fleshed 'Hayward' which is harvested at 6.5% SS content. This higher % SS content at harvest allows 'Hort 16A' to be edible right at harvest (Clark et al., 2004; Mitchell, 1994). Sensory panels have been shown to prefer 'Hort 16A' kiwifruit when the % SS is between 16 – 18% but will most likely accept kiwifruit with a % SS between 12-14% (Harker et al., 2009). A hue angle of 108° or below produces the signature yellow color that consumers have come to expect in the golden cultivars of kiwifruit (Ferguson, 1999). Due to the slow development of the signature yellow color during cold storage a hue angle at or below 103° and a % SS greater than 10% is recommended at harvest of 'Hort 16A' (Patterson et al., 2003).

Most storage research in kiwifruit has been completed on the 'Hayward' kiwifruit, as it is the current industry standard. 'Hayward' has a storage life of three to six months, which is one of its more valuable attributes (Nishiyama, 2007). Over this time in cold storage the firmness will decrease until it reaches a firmness of around 1.2 kg of pressure. When the firmness of the kiwifruit reaches 1.2 kg of pressure at pre-shipment for retail, that kiwifruit is considered past its prime. This is because 'Hayward' kiwifruit shipped at 1.2 kg results in an optimum eating pressure of 0.6 – 0.08 kg at market (Lallu, 1989; Lallu, 1997). The newer industry standard for golden kiwifruit 'Hort 16A' has an expected storage length of 12 – 16 weeks at 0 °C (Patterson et al., 2003). Due to time in

cold storage, 'Hort 16A' kiwifruit will decrease in pressure similar to 'Hayward'. The difference being that 'Hort 16A' firmness can decrease until it reaches 0.46 kg of pressure (Zespri, 2010). The optimum eating pressure for 'Hort 16A' is 0.46 kg - 1 kg pressure (Patterson et al., 2003; Zespri™, 2010).

Due to the earlier harvest time of 'AU Golden Sunshine' compared to 'Hort 16A', there is potential to extend the seasonal availability of golden kiwifruit if the quality of 'AU Golden Sunshine' is comparable to the industry standard. This would be beneficial and well accepted according to Jaegar et al. (2003), where it is stated that development of an early or late maturing selections similar to 'Hort 16A' will supply exports with yellow kiwifruit for a longer period of time and sustain consumer interest in the yellow kiwifruit.

The objectives of this study were to compare the fruit quality attributes of 'AU Golden Sunshine' to 'Hort 16A' in regards to firmness, internal and external color, TA, SS, SS:TA, and % DW over time in cold storage.

## **Materials and Methods**

*Actinidia chinensis* 'AU Golden Sunshine' and 'Hort 16A', were harvested on September 16<sup>th</sup>, and October 12<sup>th</sup> 2010 respectively from the Chilton Research and Extension Center. Kiwifruit were monitored weekly for hue angle, % SS, and % DM and harvested when the hue angle was below 108°. Kiwifruit were separated according to weight and placed into commercial kiwifruit shipping trays with appropriate tray inserts. Size 39 (71-76g) kiwifruit were used for this direct comparison study. Size corresponds to a specific weight in grams of harvested kiwifruit. Kiwifruit trays are labeled based on the number of fruit for a certain size that will fit in a commercial kiwifruit tray, for

example a number 30 tray holds 30 kiwifruit sized 30 (88-97g). Six trays of each variety were then transported to Auburn University, Auburn AL, to implement the study. Ten fruit from each variety were kept at room temperature (20 °C) for 24 hours prior to initial fruit quality measurements. Remaining fruit in trays were placed in cold storage room set at 0 °C and 95 % relative humidity. Two data loggers were placed in cooler to monitor the temperature and the relative humidity. Temperature and relative humidity were maintained at  $1\text{ °C} \pm 0.83\text{°C}$  and  $91\% \pm 4\%$ , respectively. For the remainder of the study, ten fruit from each cultivar were randomly selected every 13 days and placed in trays on the laboratory bench top at room temperature for 24 hours prior to the analysis. Each individual fruit was considered a replicate.

### **Fruit Quality Analysis**

Fruit quality for ten individual fruit was determined initially on September 17<sup>th</sup> for ‘AU Golden Sunshine’ and October 12<sup>th</sup> 2010 for ‘Hort 16A’, and then on 14 day intervals for the duration of the study (98 d). The following data was collected for each fruit: weight, length, width, percent soluble solids (SS), color (IC), internal and (EC) external, firmness (kg), percent dry weight (% DW), titratable acidity (TA) and the ratio of SS:TA. Fruit analysis continued until the fruit reached a firmness that was less than 0.46 kg of pressure or until the fruit was determined to be unsalable due to injury. Less than 0.46 kg of firmness was used as a termination point because according to Zespri™ the optimum eating pressure is between 0.46 kg - 1 kg pressure (Patterson et al., 2003; Zespri™, 2010). All fruit had two outer color measurements and one internal color measurement performed using a Minolta CM-2002 spectrophotometer (Minolta, Tokyo,



Japan). Internal color was determined by cutting a 1 mm slice from the shoulder of the kiwifruit, and measuring the hue angle with the colorimeter. Colors on a color wheel can be represented by degrees around the 360 degree wheel where red purple is represented at 0 degrees, yellow at 90 degrees, blue green at 180 degrees, and blue at 270 degrees (McGuire, 1992). Degree readings make color readings easier to see and less likely to misinterpret when compared to other measurements of color (McGuire, 1992). Firmness was then taken on the same cut area on the shoulder where the internal color was taken. Firmness was measured with a bench top penetrometer using an 8-mm (5/16 inch) probe (Model FT 327, McCormick Fruit Tech, Yakima, Washington). Firmness was measured in kg of force needed to insert the 8-mm (5/16 inch) probe 1 cm into the flesh of the fruit.

A 10 mm section was cut from both the flower and the vine end of the fruit for use in measuring the SS. SS content for both fruit ends were determined using a Leica Mark II Abbe refractometer (Leica Inc., Buffalo, NY, USA). The average of the top and bottom SS was used to determine fruit SS content. The remainder of the kiwifruit was cut in half and a 3 mm slice was taken from the middle section of both halves. These slices were weighed and then both dried in a food dehydrator (Excalibur products, Sacramento, California) at 62.7 °C for 24 hours. They were then re-weighed to achieve the percent dry weight ( $DW/FW \times 100$ ).

Twenty-five g of the remaining kiwifruit samples were added to 100 ml of HPLC water from a Millipore Direct-Q5 filter system (Millipore Corp., Bedford, MA). This was blended until all the kiwifruit was in a slurry consistency. This slurry was kept in motion with the help of stir plates until ready to be poured into test tubes. Twenty-five grams of the slurry was placed in test tubes and spun in a centrifuge (Model J2-21; Beckman

Centrifuge, San Antonio, TX) for 15 min at 15000 g<sub>n</sub> to separate out the solids and extract the supernatant. The supernatant was then be poured through grade 50 cheesecloth filter into 50 ml beakers. From these beakers, 5 ml of supernatant was added to 25 ml of HPLC water for a final volume of 30 ml. TA was measured using an automated titrimeter (Metrohm Titrino Model 751 and Metrohm Sample Changer; Metrohm Corp., Herisau, Switzerland) and associated software (Brinkmann Titrino Workcell 4.4 Software; Brinkmann Corp., Westbury, NY, USA). The automatic titrimeter was housed in a Fisher Scientific refrigerated chromatography chamber maintained at 10 °C (Model Isotemp Laboratory Refrigerator; Fisher Scientific, Raleigh, NC, USA). A 0.1 M solution of NaOH was titrated to the endpoint of pH 8.1 and the results were expressed in citric acid equivalent using the formula: [(mL NaOH × 0.1N × 0.064 meq·g<sup>-1</sup> of juice) × 100].

Data was analyzed using Proc Mix and Proc Glimmix of Statistical Analysis Systems (Version 9.1; S.A.S. Inc., Cary NC), and least squared means separation using Tukey's least significant difference at  $\alpha = 0.05$ .

## **Results and Discussion**

The storage life was similar for 'AU Golden Sunshine' and 'Hort 16A', as fruit from both cultivars stored for approximately 14 weeks (98 d) (Table 3.1). Fruit from both cultivars were too soft and deemed unmarketable by week 16 (data not shown). This is consistent with the previously reported expected storage life of 12 – 16 weeks for *Actinidia chinensis* fruit (Patterson et al., 2003). Though there were differences in fruit firmness in weeks 4 and 8, firmness tended to be similar for the cultivars over the length

of time in cold storage. As expected, fruit firmness decreased in a linear fashion due to length of time in cold storage for both cultivars (Table 3.1).

There were differences in fruit quality attributes between the two cultivars. ‘Hort 16A’ fruit was consistently higher in SS content throughout this study (Table 3.1, Fig. 3.1). There was an average SS difference of 2.68 %, and ‘Hort 16A’ had greater SS content in all weeks except week 4. Kiwifruit are usually preferred when the SS content is 12.5 % or higher, and thought to have a sour flavor when the % SS is below 11.6 % (Crisosto and Crisosto, 2001; Harker et al., 2009). Both cultivars were consistently above the preferred 12.5 % SS content after weeks in cold storage. The acidity of the fruit was similar for the two cultivars, as there were no differences in TA for most weeks of data collection (Table 3.1). ‘AU Golden Sunshine’ fruit had greater TA in weeks 0, 8, and 14, but, in general, there were no differences in TA between the cultivars. Primarily due to higher SS content, ‘Hort 16A’ fruit had consistently greater SS:TA compared to ‘AU Golden Sunshine’ fruit (Table 3.1, Fig. 3.2). This indicates that ‘Hort 16A’ would likely be perceived as a sweeter fruit compared to ‘AU Golden Sunshine’. Typical of maturing fruit, SS content and SS:TA increased linearly, while TA decreased linearly due to length of time in cold storage.

*A. chinensis* fruit develop darker external and internal color as fruit matures, which was observed in the present study. A lower hue angle corresponds to a darker color, and both external and internal hue angles decreased linearly due to length of time in cold storage (Table 3.1). External color was similar for the two cultivars in most weeks, though there were variable differences in weeks 0, 4, and 10. Internal color measurements fluctuated somewhat between the cultivars. There were no differences on

4 of the 8 data collection dates, but 'AU Golden Sunshine' fruit had a lower hue angle compared to 'Hort 16A' on 3 dates. Both cultivars developed the signature dark yellow color that is expected in golden kiwifruit (Ferguson, 1999).

'Hort 16A' fruit had consistently higher % DW compared to 'AU Golden Sunshine' (Table 2.1, Chart 2.3). There was an average difference of 2 % DW. As % DW is primarily due to the amount of soluble solids or the sugar content of the kiwifruit, which contributes to a sweeter flavor, sensory panelists prefer kiwifruit with higher % DW (Burdon et al., 2004; Jordan et al., 2000). Both cultivars had well above the recommended 15% DW that is required across Europe as well as the Middle Eastern countries (Rural Payments Agency, 2010). The % DW remained consistent throughout the time in cold storage, as there were no trends for either cultivar.

In summary, 'AU Golden Sunshine' and 'Hort 16A' fruit can be stored for at least 14 weeks before firmness decreases below optimum eating quality (Patterson et al., 2003). Fruit firmness and storage life were similar between the two cultivars. Internal color development was similar for the cultivars, though 'AU Golden Sunshine' tended to be a darker yellow color compared to 'Hort 16A'. There were differences in fruit quality attributes between the two cultivars, as 'Hort 16A' fruit consistently had greater SS content, SS:TA, and % DW compared to 'AU Golden Sunshine'. 'AU Golden Sunshine' was harvested 25 d before 'Hort 16A', whereas the initial fruit set of 'AU Golden Sunshine' was approximately 2 weeks after 'Hort 16A'. Hence, the lower SS, SS:TA, and % DW observed in 'AU Golden Sunshine' fruit is likely due to the shorter fruit development period. Despite having a lower SS content and % DW, 'AU Golden Sunshine' fruit was above the 12.5% SS that panelists are looking for to perceive a sweet

flavor, and well above the minimum required 15 % DW (Crisosto and Crisosto, 2001). Sensory panels had the greatest “liking” of kiwifruit with a % DW between 16 – 18% DW which both cultivars Alabama achieved in this study (Harker et al., 2009; Jaeger et al., 2011). Likely due in part to the warm growing environment in central Alabama, fruit from both cultivars developed a relatively high % DW that is preferred by consumers (Jaeger et al., 2003; Snelgar et al., 2005).

Currently, a hue angle of 108° or lower with a preferred hue angle of 103°, is used to determine the harvest of golden kiwifruit (Patterson et al., 2003). In the present study, ‘AU Golden Sunshine’ had a lower hue angle (104.1°) compared to ‘Hort 16A’ (105.7°) at harvest. The greater internal color of ‘AU Golden Sunshine’ at harvest could be mistakenly interpreted as advanced maturity compared to ‘Hort 16A’ at harvest. However, the lower SS content and % DW of ‘AU Golden Sunshine’ indicated that ‘Hort 16A’ was more mature at harvest. Lower % SS as well as lower % DW have been shown to be determining factors of immature fruit (Maguire et al., 2007). The darker yellow color observed in ‘AU Golden Sunshine’ is likely a cultivar trait, whereas % SS is likely a more accurate harvest index. Future research is needed to determine whether % SS content would differ between the two cultivars if they were harvested similarly based on % SS content. As expected with a longer growing season, ‘Hort 16A’ fruit consistently contains higher % DW compared to ‘AU Golden Sunshine’ fruit in central AL. Harvesting fruit when % SS content is similar will allow for the accurate determination of whether the higher % DW present in ‘Hort 16A’ fruit translates into higher % SS over time in cold storage.

## Literature Cited

- Burdon, J., D. McLeod, N. Lallu, J. Gamble, M. Petley, and A. Gunson. 2004. Consumer evaluation of 'Hayward' kiwifruit of different at harvest dry matter contents. *Postharvest Biol. and Technol.* 34:245-255.
- Clark, C.J., V.A. McGone, H.N. De Silva, M.A. Manning, J. Burdon, and A.D. Mowat. 2004. Prediction of storage disorders of kiwifruit (*Actinidia chinensis*) based on visible-NIR spectral characteristics at harvest. *Postharvest Biol. and Technol.* 32:147-158.
- Crisosto, C.H. and G. M. Crisosto. 2001. Understanding consumer acceptance of early harvested 'Hayward' kiwifruit. *Postharvest Biol. and Technol.* 22:205-213.
- FAO STAT. 2010. Top Production Kiwifruit 2008. Food and Agriculture Organization of the United Nations. Available: <http://faostat.fao.org/site/339/default.aspx>. (2010, November 6th).
- Ferguson, A.R. 1999. Kiwifruit Cultivars: Breeding and selection. *Acta. Horti* 498:43-51.
- Harker, F.R., B.T. Carr, M. Lenjo, E.A. MacRae, W.V. Wismer, K.B. Marsh, M. Williams, A. White, C.M. Lund, S.B. Walker, F.A. Gunson and R.B. Pereira. 2009. Consumer liking for kiwifruit flavor: A meta-analysis of five studies on fruit quality. *J. Food Qual. Pref.* 20:30-41.
- Jaeger, S.R., K.L. Rossiter, W.V. Wismer, and F.R. Harker. 2003. Consumer driven product development in the kiwifruit industry. *J. Food Qual. Pref.* 14: 187-198.
- Jaeger, S.R. R. Harker, C.M. Triggs, A. Gunson, R.L. Campbell, R. Jackman, and C. Requejo-Jackman. 2011. Determining consumer purchase intentions: The importance of dry matter, size, and price of kiwifruit. *J. Food Sci.* 76:177-184.
- Jordan, R. B., E. F. Walton, K. U. Klages, and R. J. Seelye. 2000. Postharvest fruit density as an indicator of dry matter and ripened soluble solids of kiwifruit. *Postharvest Biol. and Technol.* 20:163-173.

- Maguire, K.M., R. Spinelli and B. Nicolai. 2007. Within- vine variation in maturity parameters and storage potential of 'Hort 16A' (Zespri Gold) kiwifruit grown in Italy. *Acta Hort.* 753:317-324.
- McGuire, R.G. 1992. Reporting of the objective color measurements. *Hortscience* 27:1254-1255.
- Lallu, N. 1997. Low temperature breakdown in kiwifruit. *Acta. Hort.* 2:579-585.
- Lallu, N., A. N. Searle, and E. A. MacRae. 1989. An investigation of ripening and handling strategies for early season kiwifruit *Actinidia deliciosa* 'Hayward'. *J. Sci. Food Agric.* 47:387-400.
- Mitchell, G.F. 1994. Composition, maturity, and quality, p 94-98. In: J. Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling*. ANR Publ: Oakland, CA.
- Nishiyama, I. 2007. Fruits of the *Actinidia* genus. *Adv. in Food Nutr. Res.* 52:293-324.
- Patterson, K., J. Burdon and N. Lallu. 2003. Hort 16A Kiwifruit: Progress and issues with commercialisation. *Acta. Hort.* 610.
- Rural Payments Agency 2010. Marketing standards kiwifruit (*A. chinensis* or *A. deliciosa*). Rural Payments Agency uk. Gov. 16<sup>th</sup> July 2011.  
<<http://rpa.gov.uk/rpa/index.nsf/vContentByTaxonomy/9A5CB006DE66FD278025712E0036C095?OpenDocument>>.
- Schultz, T. and E. McNeil. 1994. Marketing, p 3-5. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling*. ANR Publ: Oakland, CA.
- Snelgar, W.P., P.E.H. Minchin and P. Blattmann. 2005. Altering growth and maturation of *Actinidia chinensis* 'Hort 16A' fruit by heating individual berries. *J. Hort Sci. Biotech.* 80:779-785.
- Zespri. 2010. Storage and handling of kiwifruit. New Tech Web inc. Available: <http://www.zesprikiwi.com/storage.htm> (2010, August 6th).

## Appendix A: Tables

Table 3.1. Effects of the interactions of cold storage duration and variety on firmness, % SS, % TA, SS:TA ratio, % DW, external color and internal color of ‘AU Golden Sunshine’ and ‘Hort 16A’.<sup>z</sup>

Attribute <sup>y</sup>	Fruit <sup>x</sup>	Weeks								Sign <sup>w</sup>
		0	2	4	6	8	10	12	14	
Firm (kg)	GS	6.55ns <sup>v</sup>	4.18ns	3.73b	1.78ns	2.5a	0.54ns	0.50ns	0.82ns	L***
	HT	6.93	5.34	4.6a	2.34	1.34b	0.95	0.47	0.58	L***
SS (%)	GS	8.2b	12.2b	14.9ns	13.9b	13.6b	16.0b	13.8b	14.4b	L***
	HT	11.7a	14.8a	15.3	16.3a	17.6a	17.8a	17.7a	17.2a	L***
TA (%)	GS	1.7a	1.4ns	1.3ns	1.4ns	1.4a	1.1ns	1.2ns	1.4a	L***
	HT	1.4b	1.4	1.3	1.3	1.3b	1.2	1.3	1.3b	L***
SS:TA	GS	4.8b	8.2b	11.1ns	9.7b	9.3b	13.9ns	10.8b	10.2b	L***
	HT	8.2a	10.5a	11.2	11.9a	13.7a	15.6	13.6a	13.1a	L***
DW (%)	GS	19.6ns	19.5b	19.4b	18.4b	19.3b	19.1b	19.5b	18.8b	
	HT	20.4	21.8a	21.5a	20.6a	21.2a	22.1a	21.5a	20.7a	
EC (Hue°)	GS	71.3b	74.4ns	76.1a	70.4ns	69.4ns	63.4b	63.9ns	71.2ns	L***
	HT	77.5a	73.9	71.6b	71.3	70.5	68.8a	72.1	67.6	L***
IC (Hue°)	GS	104.1ns	101.9ns	100.1b	100.1b	103.6ns	97.3b	103.1a	99.4ns	L***
	HT	105.7	104.8	104.1a	103.9a	102.2	100.6a	99.9b	100.3	L***

<sup>z</sup>The fruit size × week of cold storage interaction was significant at  $\alpha = 0.05$  for all fruit quality attributes.

<sup>y</sup>Firm= Firmness, SS= Soluble solids, TA= Titratable acidity, SS:TA= Soluble solids Titratable acidity ratio, % DW= % Dry weight, EC= External color, IC= Internal color.

<sup>x</sup>GS= ‘AU Golden Sunshine’, HT= ‘Hort 16A’.

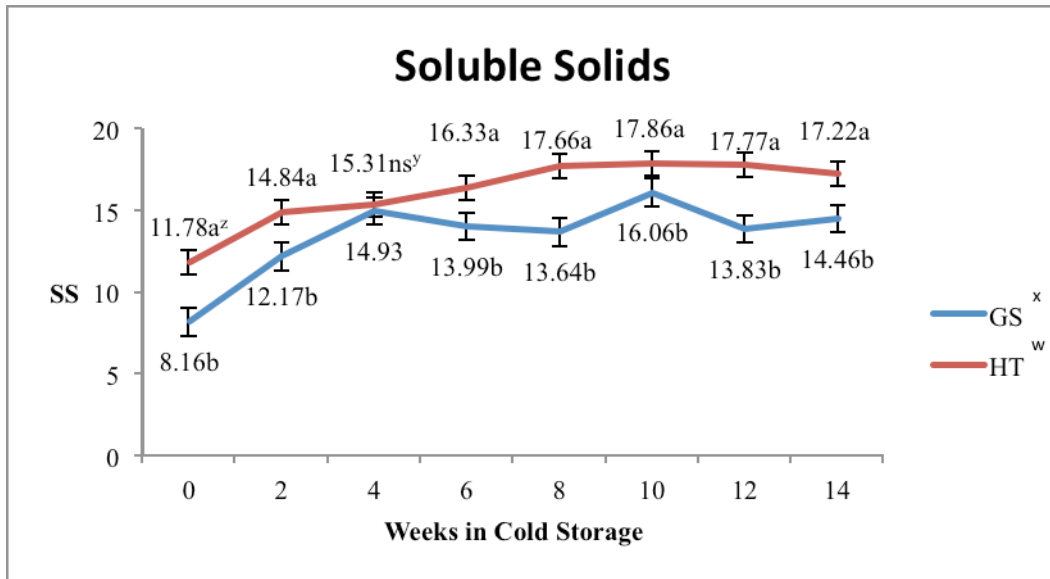
<sup>w</sup>Significant linear (L) trends using orthogonal polynomials at  $\alpha = 0.001$ (\*\*\*). Sign = Significance.

<sup>v</sup>Least squared means comparison among fruit sizes (letters in columns) using Tukey test at  $\alpha = 0.05$ , ns=not significant.



Appendix B: Figures

Figure 3.1. The least squared means of soluble solids (SS) content of ‘AU Golden Sunshine’ and ‘Hort 16A’ over 14 weeks of cold storage.



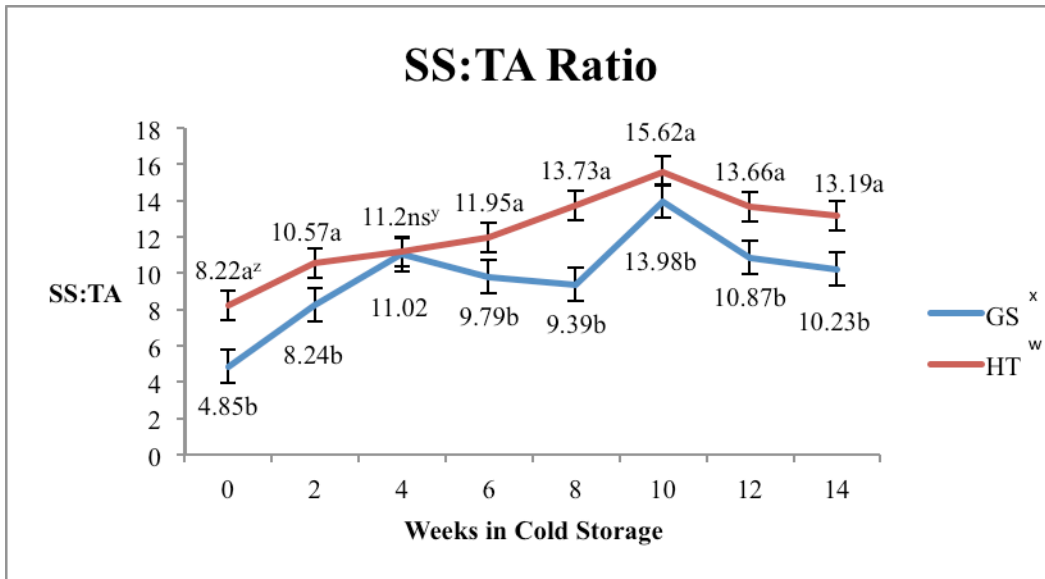
<sup>z</sup> Different letters indicate interaction was significant at  $\alpha = 0.05$  using Tukey test at  $\alpha = 0.05$ .

<sup>y</sup> ns = No significance between varieties at  $\alpha = 0.05$ .

<sup>x</sup> GS = ‘AU Golden Sunshine’.

<sup>w</sup> HT = ‘Hort 16A’.

Figure 3.2. The soluble solids and acidity ratio (SS:TA) of least squared means of ‘AU Golden Sunshine’ and ‘Hort 16A’ over 14 weeks of cold storage.



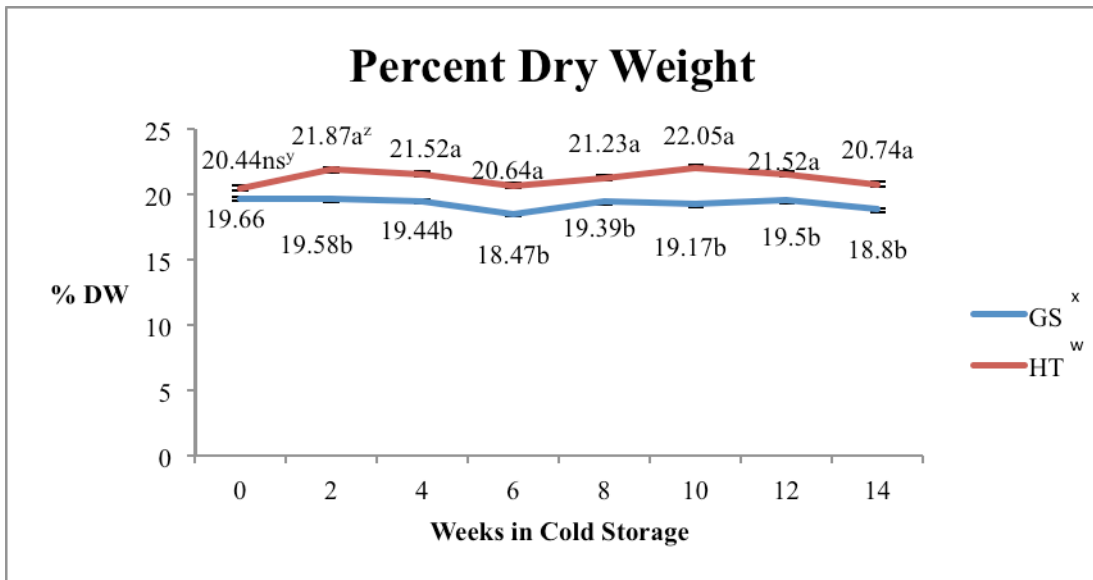
<sup>z</sup> Different letters indicate interaction was significant at  $\alpha = 0.05$  using Tukey test at  $\alpha = 0.05$ .

<sup>y</sup> ns = No significance between varieties at  $\alpha = 0.05$ .

<sup>x</sup> GS = ‘AU Golden Sunshine’.

<sup>w</sup> HT = ‘Hort 16A’.

Figure 3.3. The least squared means of percent dry weight (% DW) of ‘AU Golden Sunshine’ and ‘Hort 16A’ over 14 weeks of cold storage.



<sup>z</sup> Different letters indicate interaction was significant at  $\alpha = 0.05$  using Tukey test at  $\alpha = 0.05$ .

<sup>y</sup> ns = No significance between varieties at  $\alpha = 0.05$ .

<sup>x</sup> GS = ‘AU Golden Sunshine’.

<sup>w</sup> HT = ‘Hort 16A’.

## **Conclusion and Future Research**

Popularity of golden kiwifruit has increased and as a result, production of golden kiwifruit has risen in the top three producing countries from 504,500 tons in 1994 to 1,008,955 tons in 2010 (FAOSTAT, 2010; Schultz and McNeil, 1994). ‘Hort 16A’, the industry standard for golden kiwifruit in New Zealand, is currently a 160 million dollar industry accounting for 17 – 18 % of New Zealand’s total kiwifruit exportation (Nishayama, 2007). As golden kiwifruit popularity increases, the ‘AU Golden Dragon’ and ‘AU Golden Sunshine’ cultivars provide opportunities to extend the seasonal availability since storage life and quality attributes meet the parameters of consumer acceptability set in previous studies.

Quality attributes are important factors to new cultivars of golden kiwifruit because consumer acceptance of kiwifruit is highly dependent on the taste of the kiwifruit, understood in terms of the % DW and the % SS of the kiwifruit (Jaeger et al 2011). A kiwifruit with a high % DW and high % SS is preferred when compared to kiwifruit with lower % DW and % SS (Burdon et al., 2004; Crisosto and Crisosto, 2001; Harker, 2004; Harker et al., 2009; Jaeger et al., 2011). Consumers are willing to pay more for a higher % DM kiwifruit (Burdon et al., 2004). It has been shown that sensory panels prefer ‘Hort 16A’ kiwifruit when the % SS is between 16 – 18%, but will most likely accept kiwifruit with a % SS between 12-14% (Harker et al., 2009).

Likewise, proper storage of the fruit is essential in order to get the maximum revenue from harvested kiwifruit. The length of storage can determine the potential market of a kiwifruit cultivar and the qualities that make a kiwifruit valuable, such as fruit firmness, % DW and % SS. Most storage research in kiwifruit has been completed on the 'Hayward' kiwifruit, as it is the current industry standard. 'Hayward' has a storage life of three to six months, which is one of its more valuable attributes, compared to 'Hort 16A' which has an expected storage length of 12 – 16 weeks at 0 °C (Patterson et al., 2003; Nishiyama, 2007). As the production of golden kiwifruit continues to expand, the effect of fruit size on fruit quality and storage life is important to know for better world distribution (Schultz and McNeil, 1994).

Comparing a small, medium and large size of the 'AU Golden Sunshine', AU Golden Dragon' and 'Hort 16A' grown at the Chilton Research and Extension Center, Clanton, AL, showed a potential for the smaller kiwifruit to have a longer storage life compared to the other sized kiwifruit. However, the greater firmness from the smaller sized kiwifruit could be due to immaturity. The higher hue angle of internal color and lower % SS of the small kiwifruit at harvest compared to the medium and large sizes are signs of immaturity in the small fruit. The different bloom times as well as the placement on the vine could be other potential reasons for the difference in maturity levels between the sizes. *A. chinensis* flowers over an 11 day period with a 6-12 day period of pollination, giving rise to different levels of fruit maturity (Cheng et al., 2006). Other research has shown that 'Hort 16A' kiwifruit from inner canopy is more immature compared to kiwifruit harvested from the tips of the kiwi vine (Maguire et al., 2007).

Future research could address issues of vine placement and maturity levels in these newer varieties of golden kiwifruit.

Only the storage life of ‘AU Golden Sunshine’ and ‘Hort 16A’ could be established in this study, with both cultivars storing 14 – 16 weeks, similar to the lengths of storage in previous studies of ‘Hort 16A’ (Patterson et al., 2003). ‘AU Golden Dragon’ storage life could not be determined due to the development of chilling injury by week 10 in storage. Chilling injury was most likely a result of the low % SS of the immature kiwifruit at harvest, as it is reported that kiwifruit with a % SS below 6.3% SS stored at 0 °C have a higher likelihood of developing chilling injury (Crisosto and Crisosto, 2001; Lallu, 1997).

All three cultivars, regardless of size, increased in % SS content as time in cold storage increased. However, in a direct comparison of ‘AU Golden Sunshine’ to ‘Hort 16A’, it was found that ‘Hort 16A’ fruit had a higher % SS. Both cultivars, grown here in Alabama, had a higher % SS than the minimum 14 % SS preferred by consumers (Burdon et al., 2004).

The % DW was not affected by size or time in cold storage for cultivars ‘AU Golden Dragon’ and ‘Hort 16A’, however the ‘AU Golden Sunshine’ had a slight increase in % DW that was affected by size during the time in cold storage. Respiration might have been higher in the ‘AU Golden Sunshine’ causing the differences and changes in the % DW over the time in cold storage (Heyes et al., 2009). In a direct comparison of ‘AU Golden Sunshine’ and ‘Hort 16A’, ‘Hort 16A’ fruit had higher % DW at harvest compared to ‘AU Golden Sunshine’. However, the % DW for both cultivars stayed consistent during time in cold storage. Regardless of the differences

between the cultivars, both cultivars developed a % DW higher than the 16 – 18% that is the optimum % DW preferred by consumers.

Since harvest times and performance of ‘AU Golden Sunshine’ and ‘AU Golden Dragon’ are earlier compared to ‘Hort 16A’, there is potential to extend the seasonal availability of golden kiwifruit. This would be beneficial and well accepted according to Jaegar et al. (2003), where it is stated that development of early or late maturing selections similar to ‘Hort 16A’ will supply exports with yellow kiwifruit for a longer period of time and sustain consumer interest in the yellow kiwifruit.

These findings indicated that different sizes and maturity levels affect the quality attributes and overall storage life of *A. chinensis* cultivars. Future research is needed to determine the cause of the variation in sizes, and the subsequent effects on fruit quality and storage life. In addition, it would be interesting to determine the effects of fruit maturity on storage life, with the goal of determining appropriate horticultural maturity harvest indices for the new golden kiwifruit cultivars.

## Literature Cited

- Burdon, J., D. McLeod, N. Lallu, J. Gamble, M. Petley, and A. Gunson. 2004. Consumer evaluation of 'Hayward' kiwifruit of different at harvest dry matter contents. *Postharvest Biol. and Technol.* 34:245-255.
- Cheng, C.H., A.G. Seal, S.J. Murphy and R.G. Lowe. 2006. Variability and inheritance of flowering time and duration in *Actinidia chinensis* kiwifruit. *Euphytica*. 147:395-402.
- Crisosto, C.H. and G. M. Crisosto. 2001. Understanding consumer acceptance of early harvested 'Hayward' kiwifruit. *Postharvest Biol. and Technol.* 22:205-213.
- FAO STAT. 2010. Top production kiwifruit 2008. Food and Agriculture Organization of the United Nations. Available: <http://faostat.fao.org/site/339/default.aspx>. (2010, November 6th).
- Harker, F.R. 2004. Consumer evaluation of taste and flavor: Zespri Gold and Zespri Green. *Hort Research*. 166: 5-9.
- Harker, F.R., B.T. Carr, M. Lenjo, E.A. MacRae, W.V. Wismer, K.B. Marsh, M. Williams, A. White, C.M. Lund, S.B., Walker, F.A., Gunson and R.B. Pereira. 2009. Consumer liking for kiwifruit flavor: A meta-analysis of five studies on fruit quality. *J. Food. Qual. And Pref.* 20:30-41.
- Heyes, J.A., D.J. Tanner and A.R. East. 2010. Kiwifruit respiration rates, storage temperatures and harvest maturity. *Acta. Hort.* 880:167-174.
- Jaeger, S.R., K.L. Rossiter, W.V. Wismer, and F.R. Harker. 2003. Consumer driven product development in the kiwifruit industry. *Food quality and preference.* 14: 187-198.
- Jaeger, S.R. R. Harker, C.M. Triggs, A. Gunson, R.L. Campbell, R. Jackman, and C.Requejo-Jackman. 2011. Determining consumer purchase intentions: The importance of dry matter, size, and price of kiwifruit. *J. of Food Sci.* 76:177-184.



- Lallu, N. 1997. Low temperature breakdown in kiwifruit. *Acta Hort.* 2:579-585.  
handling strategies for early season kiwifruit *Actinidia deliciosa* 'Hayward'. *J. Sci. Food Agric.* 47:387-400.
- Maguire, K.M., R. Spinelli and B. Nicolai. 2007. Within-vine variation in maturity parameters and storage potential of 'Hort 16A' (Zespri Gold) kiwifruit grown in Italy. *Acta Hort.* 753:317-324.
- Nishiyama, I. 2007. Fruits of the *Actinidia* genus. *Adv. in Food Nutr. Res.* 52:293-324.
- Patterson, K., J. Burdon and N. Lallu. 2003. Hort 16A kiwifruit: Progress and issues with commercialisation. *Acta Hort.* 610.
- Schultz, T. and E. McNeil. 1994. Marketing, p 3-5. In: J.Hasey, R.S. Johnson, J.A. Grant, and W.O. Reils (eds). *Kiwifruit Growing and Handling*. ANR Publ: Oakland,CA.