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The Color-Add Process as Applied in Florida

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The weak natural color of some varieties of oranges and some hybrids grown in Florida has resulted in the use of a dye on the peel to improve their market appearance. While this practice is many decades old, there is little in the literature about the process and its commercial application. The currently used dye, Citrus Red No. 2, is governed by several regulations. In addition to current application practices, concerns over the safety of the dye used and the affect of the color-add process on the fruit are addressed.

The maturity of many fruits is often associated with their color. The term "Green" is often used as an antonym for "Ripe." With oranges, the color associated with maturity is usually a strong orange color. There are notable exceptions to this. In the case of the Satsuma mandarin, those cultivars that mature before the cold weather sets in exhibit a dark green peel (Anderson et al., 2012). This fruit is often harvested for select markets and sold as "Emerald Mandarins." Later, when color begins to develop this fruit is degreened, possibly color-added, and sold as "Satsuma Oranges." Another exception is fruit grown in tropical climates. Green or mostly green is the acceptable color in fruit sold locally and around the world (Stewart, 1980).

In the semitropical climate of Florida, the peel color of some varieties of citrus have little relation to their maturity. Early season fruits such as 'Hamlin' and 'Parson Brown' reach full maturity during the early fall. This usually results in the fruit having sweet, good flavored juice with an acceptable color, but with a green colored peel. The green color is due to chlorophyll. When nighttime soil and air temperatures fall below 55 °F (13 °C) the chlorophyll degrades to a colorless compound and yellow/orange carotenoids increase in the peel (Erickson, 1962; Mackinney, 1961; Rouse and Zebri, 2006 Stearns and Young, 1942; Stewart and Wheaton, 1971).

In order to be acceptable to their usual markets, Florida citrus varieties that are harvested when mature, but still have a green peel, need to be subjected to degreening by exposing them to ethylene. The degreening process used in Florida causes the chlorophyll to degrade, but the temperatures used inhibit the synthesis of the carotenoids cryptoxanthin (orange-red) and β-citraurin (red), thus leaving a fruit with a yellow, rather than orange peel (Stewart and Wheaton, 1971). By subjecting the oranges to an emulsion containing Citrus Red No. 2 (CR2) dye, the color of the fruit is more appealing to consumers. This process is normally referred to as the Color-Add process or Color-Adding (Hayward, 1964).

History

Since consumers usually purchase fresh produce based on physical appearance, color has become a significant factor in their decisions. Over time, production of citrus moved southward (Attaway, 1997; Hall, 2004; Hall and Bowers, 1989) into the warmer climate of Central and South Florida. This, coupled with the development of earlier maturing varieties of oranges, resulted in an increasing need for methods of enhancing the color of degreened fruit. An early US patent (Harvey, 1933) disclosed the use of oil soluble dyes and claimed to dye the natural waxy coating of the fresh fruit.

A subsequent formulation of Color-Add based on a soap/solvent emulsion (Handy, 1936) was developed and variations (depending on the supplier) became the standard for the industry. These formulations dyed the surface of the skin and did not normally penetrate the peel. The soap formulations were gradually phased out until the late 1970s as they were gradually replaced by formulations using non-ionic surfactants.

In order to be used for dyeing citrus, the US Food and Drug Administration (FDA) must certify the dye. In 1939, FD&C Red No. 32 was listed for this use. The FDA would examine samples of each lot produced and issue a certificate of approval. In 1956, FD&C Red No. 32 was delisted and only lots of dye with current certificates could be used until 1 Jan. 1960 (Anonymous, 1955). Citrus Red No. 2 (CR2) was listed in 1959 (Anonymous, 1959; Deshpande, 2002), and is the currently accepted dye. In 1959 a tolerance of 2 ppm was established for Citrus Red No. 2 on the skins of citrus. Since the use of FD&C Red No. 32 was allowed until 1 Jan. 1960 there was some overlap in use (CFR, 1960; Ting and Deszyck, 1960).

Florida regulations have been established that govern which varieties can be Color-Added, how applied and to the intensity of the resulting color (Anonymous, 1975). The regulations give maximum color intensities for color-added fruit based on season and variety. These values are given according to the Munsell color system. In recent years, the Munsell system has not been used extensively by the citrus industry for color measurement in Florida. Table 1 gives the Munsell values published in the regulations with their equivalents in an internationally recognized system, the 1931 CIE L*a*b (Pasquale, 2012).

Over the past decades the amount of fresh oranges has generally declined while the percentage of fresh oranges subjected to color-adding has increased (Fig. 1). These trends are indicated by the upper (Red) line indicating the percentage of oranges color-added, while the lower (Blue) line represents the number of cartons (in millions) shipped. Since the 1984–85 season the portion of the total citrus crop packed fresh has been included in Florida's statistical reports. From then until the most recent for

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Table 1. Conversion of Munsell notation to CIE L*a*b notation.

Season and typical varieties	Munsell value	CIE L*a*b (1931) D65 L	a	b
Early—Hamlin, Parson Brown, K-Early, etc.	5.4 YR 6.58/12.6)	66.49	31.28	66.80
Mid-Season—Temple Oranges, Tangelos	4.4 YR 5.90/13.1	59.76	35.33	66.75
Late—Valencia, Lue Gim Gong, etc.	4.8 YR 6.25/12.2)	63.24	32.42	62.95

Note: D65 Illuminant, 2 degree Observer.

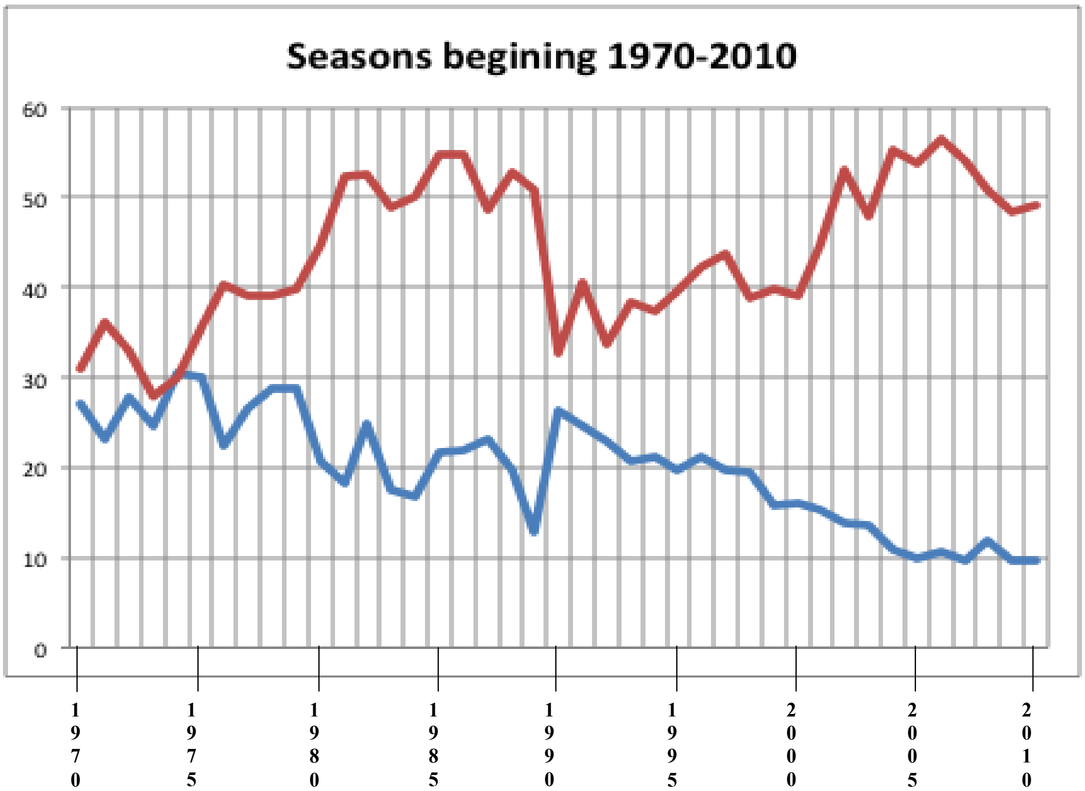

Fig. 1. 1970–2010 Seasons. 4/5 Bushel boxes oranges vs. Color-Added.

the 2010–11 season, less than 20% of the total crop including grapefruit, oranges, and tangerines has been shipped as fresh. The portion of the crop that is shipped as fresh oranges also varies. For example, during the 1982–83 season 9.2% of the total crop (all varieties) was shipped as fresh oranges while during the 2002–03 season this figure was 3.5% (Anonymous, 1983, 2003).

It can be seen that over the last 40+ seasons there has been a general decline in the number of fresh oranges shipped while the percentage of these that are color-added has increased. Several factors have a bearing on this, including variations in climate from year to year, differences in maturity date for early season varieties, the demand for fruit for processing, and market demand.

A major impact on the amount of fruit subjected to color-adding has been the shift of citrus production southward (Hall, 2004; Hall and Bowers, 1989). Freezes also have a major impact on the amount of fruit available for all uses (Attaway, 1997). When a major freeze occurs in Florida it usually comes after most packers have ceased color-adding early season fruit. The reduced availability of fruit results in higher prices paid by the processing plants, which can encourage growers to sell uncommitted fruit to processers rather than packers. By reducing the availability of fresh fruit not requiring color-adding, the percentage of the crop color-added is increased.

Application

In Florida the color-add product is supplied as a concentrate to be diluted for use. The soap-based formulations formerly common in Florida were gradually phased out and were almost completely gone by the mid 1970s. These were replaced by formulations based on non-ionic emulsifiers. One advantage to the packer was that soap-based concentrates were designed for dilution in the 25–30:1 range while the non-ionic based products were designed for dilution at 250–300:1 (Hall and Sorenson, 2006). Other advantages of the non-ionic formulations over the soap-based are that the latter required the use of softened water and the maintenance of an alkaline pH for optimum results (Hayward, 1964).

In practice, the diluted concentrate is applied to degreened fruit for the appropriate time and temperature. Florida regulations limit the treatment time for oranges to 4 min and the maximum temperature as 120 °F (49 °C). For 'Temple' oranges and tangelos the maximum time is 2½ min at a maximum temperature of 115

°F (46 °C) (Anonymous, 1975). In actual practice many packers choose to use lower temperatures and less time.

A typical applicator (usually referred to as a "dye tank") consists of a level conveyor that passes above a rectangular tank that is the width of the conveyor, about 18 inches deep, with a capacity of 300 to 500 US gallons. Pans extend from the tank to the ends of the conveyor to catch the excess dye, as it is flooded over the fruit. The dye is heated and pumped to an overhead system of perforated pans that "rain" the dye onto the fruit below (Fig. 2).

The entire apparatus is enclosed except for the entry and exit areas, which are often fitted with flexible flaps. This helps retain the tank's temperature, and retards the loss of solvents due to evaporation.

Loss of solvent due to evaporation is greatest when there is excessive start and stop operation or the preparation remains heated for an extended period of time. When too much solvent is evaporated relative to the proportion of CR2, the excess dye will precipitate and be useless unless more solvent is added. Florida's two major color-add suppliers offer a solvent formulation, without dye, to be used to replenish solvent loss. HDH Agri Products, LLC offers its product under the name "Color Booster."

The amount of replenishing solvent added depends upon a number of factors: the quantity of fruit processed in a single day, the intensity of color desired by the packinghouse management, the condition of the application equipment, etc. Over the years it has been observed that the amount of solvent used may vary among using none to using several volumes of solvent to one of dye concentrate.

Misconceptions

Over time several misconceptions regarding color-add have become part of the "folklore" of the postharvest industry. Among these are that CR2 penetrates the peel and enters into the fruit, and that CR2 is taken up into the oil glands of the fruit. Another is that color-adding contributes to decay and/or shortens the storage life of the fruit. Some also believe that the color-add process causes peel injury or rind breakdown.

As to penetration in the peel, when comparing the method of determining CR2 residues by macerating the peel in a solvent and chromatographically separating the dye for analysis (Ting, 1955; Ting and Deszyck, 1960) with surface washing with chloroform (Ting and Rouseff, 1986), no difference in recovery was found. From this it can be concluded that CR2 does not penetrate the peel. Microscopic examination of color-added oranges at the USDA ARS in Fort Pierce, FL, found no penetration of the peel in commercially color added oranges (Narciso, personal communication).

It should be noted that in one published study trace amounts of FD&C Red 32 were found in the juice of 'Pineapple' oranges in the laboratory (Ting, 1955). Since this fruit was hand extracted, and probably sliced with a knife, it is probable that dye from the surface was carried across the face of the fruit and thus into the juice. This effect would be similar to that documented with bacteria on the surface of fruits (Gayler et al., 1955).

Studies on 'Temple' and 'Ambersweet' oranges (Hayward et al., 1962; Hearn, 1990) demonstrated that there were no significant differences in either decay or shelf life between color-added fruit and controls. More significant differences were found in differing storage conditions (Wardowski, 1981).

The color-add process does not cause rind injury and stem end rind breakdown unless applied at extreme temperatures, extended times, and/or at concentrations several times stronger than normal (Hall and Bowers, 1989). The dye will, however, stain injured areas heavily, thus making them more obvious (Eckert and Eaks, 1962).

Safety

Some concern about the safety of Citrus Red No. 2 (CR2) has been raised because the International Agency for Research on Cancer (IARC) gives it a 2B risk rating as a carcinogen. The 2B rating indicates that it is a possible carcinogen; a rating of 1 means a proven carcinogen in humans; and a 2A means a probable, but not proven risk.

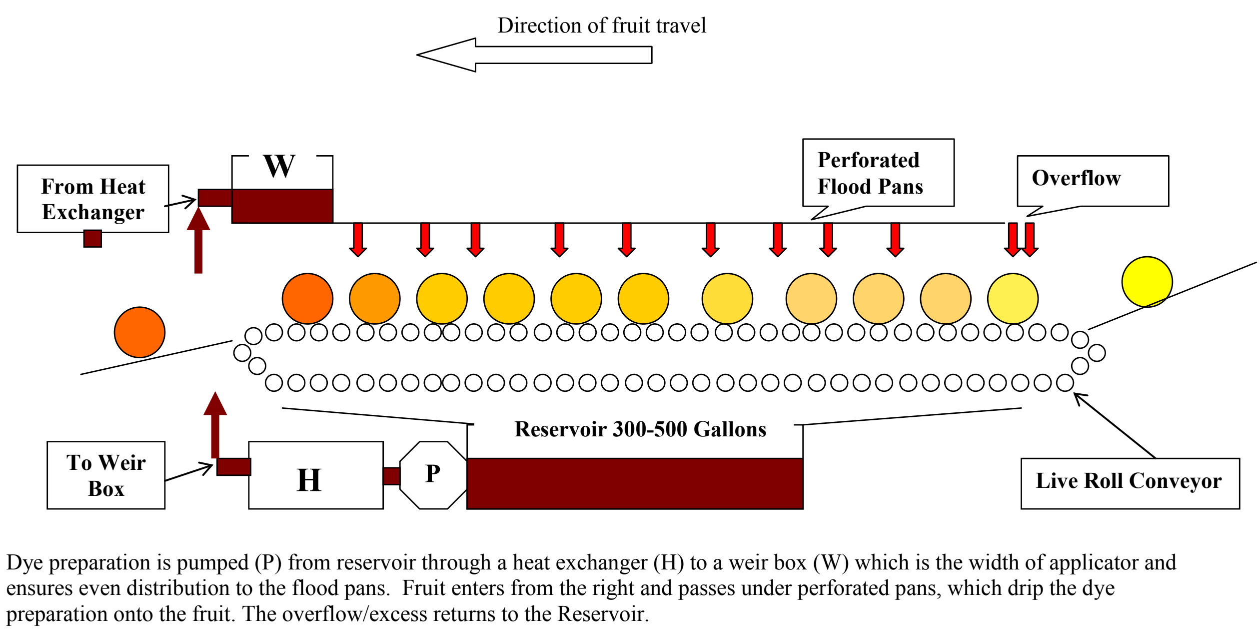

Fig. 2. Typical dye applicator operation.

A 1969 report of the Food and Agriculture Organization (FAO)/World Health Organization (WHO) cites two published studies used in support of this conclusion (Dacre, 1965; Sharratt et al., 1966; WHO/FAO, 1969). A third published study cited demonstrated that CR2 was broken down by intestinal bacteria and did not accumulate in the body beyond a certain level and then began to disappear (Radomski, 1961).

Dacre (1965) fed massive doses of CR2 over the lifetime of rats and mice and noted "Although the bladder appears to be the sole target organ for Citrus Red No. 2, this study does not demonstrate that the colouring (sic) is a weak bladder carcinogen."

In Sharratt et al. (1966), it was stated: "The 'no-effect' level in rats was estimated to be a dietary concentration of 0.1% CR2. Equivalent to approximately 40 mg CR2/kg/day." Using these figures, and assuming oranges with the maximum 2 ppm residue, a 50 kg (110 lb) human would have to consume the peel of approximately 2200 lb (1000 kg) per day for their normal life span to reach the "no-effect" level of exposure. For purpose of comparison a typical 48 carton pallet of 4/5 bushel cartons of Florida oranges contains 2160 lb of fruit (Fig. 3). Sharratt and co-authors conclude: "…for the particular use proposed, the minimal response reported in these studies can be safely ignored,"

In 1978 the Commissioner of Food and Drugs, Donald Kennedy, reported that after a review of the scientific data, due to the amounts of potential exposure, the use of CR2 posed no hazard to human health (Grierson and Wardowski, 1978; Kennedy, 1978).

The Center for Science in the Public Interest (CSPI) states regarding CR2 that: "The amounts of this rarely used dye that one might consume, even from eating marmalade, are so small that the risk is not worth worrying about." (CSPI, 2012).

It may also be noted that a single ton of oranges contains approximately 15 lb of *d*-limonene which is more that the LD_{50} (Oral) for a 110-lb person (Sun, 2000).

Another area of growing concern in packinghouses is food safety. Of special concern is the potential for bacterial contamination. While the modern color-add formulations based on non-ionic emulsifiers will perform adequately over a wide pH range, it had been noted that maintaining a pH above 9.0 results in negative tests for the presence of coliform bacteria. The chapter "Nutrition and Growth of Bacteria" indicates that a pH of 9.5 will prevent the growth of most bacterial species of public health concern (Todar, 2012). Temperature also plays an important role in bacterial growth and few species are able to grow when the temperature is above 45 °C (113 °F), the temperature in the Color-Add process.

Residue

In 1955, a method for determining the residue of FD&C Red No. 32 based on the maceration of the peel, followed by chromatographic separation, was published (Ting, 1955). Subsequently the same method was demonstrated to effectively determine residues of CR2 (Hayward et al., 1962; Ting and Deszyck, 1960). In 1986, a procedure based on simply washing the surface of color-added oranges with chloroform yielded as good or better recovery than the earlier published method (Ting and Rouseff, 1986). This result was similar to that found by surface washing fruit treated with FD&C Red 32 (Ting, 1955).

While the US federal maximum residue for CR2 is established at 2 ppm based on the whole fruit weight, published studies have found that the actual residue is considerably less than that, ranging from 0.5 to 1.1 ppm (Hayward et al.,1962; Ting and Deszyck, 1960). These lower residue findings may have contributed to at least two authors erroneously reporting that the maximum allowable residue was 0.5 ppm (Ladaniya, 2008; Ting and Rouseff, 1986).

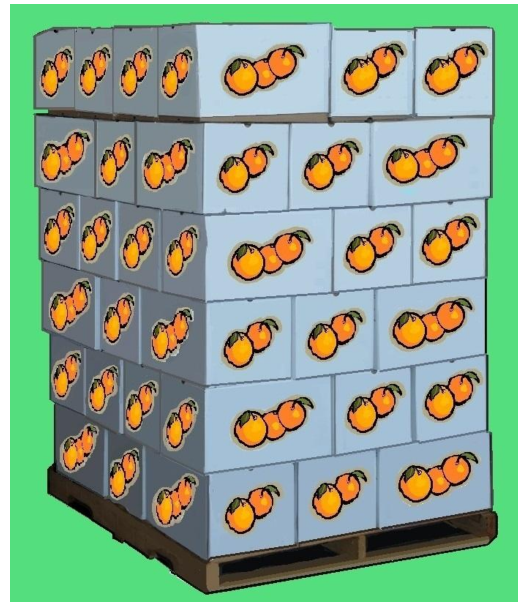

Fig. 3. Forty-eight 4/5 bushel cartons, 2160 lb.

Lessons Learned

During the last several years (1974–2013) this author has worked with the Color-add products of several service companies (Brogdex, American Machinery, Decco, Fresh Mark, and HDH Agri-Products). This has provided insight in better application and some of the problems that can result from misuse.

Most of the applicators in use today are several decades old. Packing lines were originally equipped with variable speed drives; these have become non-functional and have been replaced with fixed speed drives. Most of these have been set to pass the fruit through the applicator in less than 2½ min. In order to compensate for this, some operators increase the amount of dye concentrate used.

Poor or neglected maintenance can result in situations where the recirculating pump can suck air, thus causing excessive foaming. Using antifoam in excess can result in an oily build-up on the applicator rollers that trap dye and will cause spotting or ringing of the fruit. Ringing is the result of an orange contacting a live roll that has dye build-up.

Oranges from the grove may have *E. coli* on their surface (Pao and Brown, 1998). Since during use the dye applicator can accumulate leaves, soil, pieces of broken fruit, etc., any bacteria that escape the cleaning or pre-grading steps could survive therein. Maintaining the pH near 9.5 and the temperature at the maximum allowable has resulted in eliminating *E. coli* and other bacteria. Some operators have expressed the opinion that the coloring appears more uniform.

The two most critical factors in a uniform color-add applications are time and temperature. Under pressure to pack more fruit with existing equipment, many packers shorten the time and if the temperature measuring equipment is not accurate, unsatisfactory color may result.

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