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EFFECTS OF MECHANICAL HARVESTING ON THE QUALITY OF SMALL FRUITS AND GRAPES

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Development of mechanical harvesters have been important research objectives for research scientists in Land-Grant Institutions, in the U.S. Department of Agriculture (USDA), and in private industry in recent years. These developments have resulted in a revolution in mechanical harvesting and resulted in the need for new handling methods for the mechanically harvested crop. Quality of the raw product as well as that of the finished product can depend upon conditions during harvesting, handling, transporting, and processing. These can be influenced by environmental conditions, cultivar, cultural practices, and handling procedures prior to processing. Mechanical harvesting has shown a high degree of success in the small fruit and grape industry when these influences are considered. More and more the techniques associated with mechanical harvesting that are necessary to achieve quality in small fruit crops and grapes and their products are being discovered. Most small fruit crops for processing can now be mechanically harvested with varying degrees of success; however, this report will concentrate on the influence of mechanical harvesting on quality of cane fruits, strawberries, blueberries, and grapes. These crops were selected since they serve to illustrate the different types of quality problems that have been encountered. Also, solutions to quality problems will be discussed for each of these crops.

CANE FRUITS

Research on mechanical harvesting of cane fruits has been conducted at several locations in the United States, Canada, and Europe, and the majority of such research has been on red raspberries and blackberries (Booster and Bullock 1965 Crandall et al. 1965, Crandall et al. 1966, Fejer and Spangelo 1973, Gilfillan 1971, Hughes and Ricketson 1971, Kattan et al. 1965, Kattan et al. 1964, Martin and Lawrence 1976, Mason 1974, Morris et al. 1970, Morris et al. 1978, Morris et al. 1981, Nyborg and Coulthard 1969).

The design and subsequent developments in the cane fruit harvester developed at the University of Arkansas (Kattan et al. 1965, Kattan et al. 1961, Kattan et al. 1964, Morris et al. 1970, Morris et al. 1978, Morris et al. 1981) exploit fruit abscission as the basis of harvesting. This harvester utilizes a shaking mechanism to remove the fruits from the canes. Because ease of abscission increases with maturity, the fruit can be selectively harvested as the fruit matures.

Machine-harvested berries are larger and have a higher percentage of total soluble solids, lower acidity, and superior color than do hand-harvested berries (Table 1). Processed berries that have been machine-harvested have been rated superior to hand-harvested berries for wholeness, flavor, and color (Table 1). Booster and Bullock (1965) have also reported that mechanically harvested blackberries have higher total soluble solids than hand-harvested fruit.

One of the most important influences on quality of machine-harvested berries is temperature. Research at the University of Arkansas has shown that blackberries that are mechanically harvested and processed immediately have good processed quality even if the berry temperature is high at the time of harvest. However, berries that are machine

Table 1. Effect of method of harvest and mechanical shaker frequency on quality of 'Raven' blackberries.[a]

Quality determinations	Harvest Method: Hand	Shaker rpm: 475	Shaker rpm: 237	L.S.D @ 5%
Raw product				
Berry wt. (g)	3.0	3.5	3.6	0.3
Soluble solids (%)	13.2	13.5	13.7	0.3
Tit. acidity (ml)[b]	5.7	4.7	4.3	0.4
CDM[c] "L"	10.8	9.8	9.4	0.6
CDM "a"	14.8	10.9	10.0	1.9
Processed product[d]				
Wholeness	5.3	5.7	6.7	1.2
Flavor	4.6	6.8	7.2	1.4
Color	4.0	7.2	7.0	1.2
CDM "L"	12.8	11.7	11.7	0.7
CDM "a"	15.8	13.3	13.1	1.2

[a] From: Morris et al, 1966.

[b] Ml of N/10 NaOH required to titrate 5g puree to pH 7.

[c] Color Difference Meter; standardized to a white tile ("L"=92.3, "a"-1.9, "b"=1.3).

[d] Scale of 1-10 with 10 being best.

[a]From Morris et al., 1966
[b]Ml of N/10 NaOH required to titrate 5g puree to pH 7
[c]Color Difference Meter; standardized to a white tile (l=92.3, a=1.9, b=1.3).

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harvested at high temperature (36^{o}C) deteriorated more rapidly during storage than berries hand-picked at the same high temperature. Machine harvesting at the lowest possible temperature would be advantageous for maintaining fruit quality during handling and storage. Removal of the field heat from the berries immediately after harvest by refrigeration or by the use of a high CO_2 atmosphere (e.g., 20 to 40%) can prolong postharvest quality of machine-harvested blackberries after harvesting the fruit at high temperature (Morris et al. 1981).

Modifications of old cultural systems for growing machine-harvested cane fruits are important for successful mechanical harvesting of cane fruits. A mechanized pruner has been developed which not only reduces the labor required for pruning, but also properly shapes the hedgerow for maximum harvesting efficiency of erect cane fruits (Morris, 1980). Mechanical pruning and leaving old canes in the hedgerow did not result in lower yields or quality (Morris et al. 1978).

Other preharvest treatments can improve quality of cane fruits. Treatment of cane fruits with the growth regulator ethephon prior to harvest not only reduces the number of required harvests when used as a mechanical harvesting aid, but it increases color and lowers acidity of both raw and processed blackberries (Morris et al. 1978, Sims and Morris 1982). Although preharvest calcium sprays have not been effective in improving initial firmness of machine-harvested blackberries, they improved firmness after a 24-hr holding period (Morris et al. 1980).

Most insects can be eliminated from cane fruits prior to machine harvest by following recommended spray programs for the specific insect problem. However, insects in machine-harvested cane fruits can be removed by a washing technique (Brekke et al. 1965) in which infested berries pass through water containing a 0.1% nonalkaline anionic wetting agent. A water spray is then used to remove insects, debris, and wetting agent. Ninety-five percent of the insects can be removed by this method with no loss of quality.

STRAWBERRIES

Historically, strawberries have been considered to be among the least adaptable crops to mechanical harvesting. There are 2 obstacles; (1) lack of cultivars with firm fruit that ripen uniformly and (2) the weight of fruit on high-yielding cultivars causing the fruit's supporting truss to sag to the ground. Mechanized harvesting and handling systems have still been developed with varying degrees of success (Booster 1973, Booster 1974, Booster et al. 1970A, Booster et al. 19708, Denisen and Buchele 1967, Hansen 1976, Hecht 1972, Kattan et al. 1967, Kemp 1976, Nelson and Kattan 1967, Nelson and Kattan 1969, Quick and Denisen 1970, Ruff and Holmes 1976, Stang and Denisen 1971).

Several harvesting principles were evaluated in the process of developing a mechanical harvester for strawberries at the University of Arkansas (Kattan et al. 1967, Morris et al. 1978, Nelson and Kattan 1967, Nelson and Kattan 1969, Nelson et al. 1978, Nelson et al. 1976). One approach included cutting or clipping the fruit from the plant, but a majority of the large fruit was not harvested since they were on the ground. A harvester that utilizes a pneumatic stripping system was designed at the University of Arkansas in which a stream of air lifts the fruit into position and a comb-brush picking belt strips the fruit from the plant. The strawberries are given a once over harvest when a majority of the crop has developed acceptable color.

Work at the University of Arkansas has shown that certain cultivars (e.g., Cardinal and A-5344) of strawberries are more adapted to machine harvesting, cleaning, and sorting without loss of quality (Morris et al. 1978, Morris et al, 1974, Morris et al. 1976, Morris et al. 1979, Nelson et al. 1978, Nelson et al. 1976). These cultivars have concentrated ripening patterns and firm fruit. Each cultivar also has an optimal time of harvest, after which quality and/or usable yield will decrease (Morris et al. 1978, Morris et al. 1974, Morris et al. 1976, Morris et al. 1979, Morris et al. 1980, Nelson et al. 1978). Most cultivars suited for machine harvesting in Arkansas have a 5- to 6-day optimal period for a once-over harvest (Morris et al. 1978, Morris et al. 1979).

The quality of machine-harvested fruit from certain strawberry cultivars is also improved by prior hand picking (Morris et al. 1979, Morris et al. 1980). Fruit remaining on the plants after 1 or 2 hand harvests had a higher percentage of ripe fruit in the once-over harvest than machine harvested fruit not preceded by a hand harvest. After 1 or 2 hand pickings, total soluble solids, shear or firmness, and color intensity of the composite once-over machine-harvested fruit was the same as or higher than that of hand-harvested fruit (Morris et al. 1980). Percentage of soluble solids, acidity, and color were lower, in general, as compared to the quality of hand-picked fruit, but these qualities tended to improve as the number of hand pickings prior to machine harvest was increased (Morris et al. 1980).Sensory evaluation of fruit puree from both machine-harvested and handpicked fruit was rated as acceptable (Morris et al. 1979, Morris et al. 1980).

One of the most objectionable aspects of machine-harvested strawberries is the presence of green fruit from once-over harvests. In-plant equipment has been developed with the capability of separating the strawberries into distinct maturity classes (Morris et al. 1978, Morris et al. 1974, Morris et al. 1976, Morris et al. 1979, Nelson et al. 1978, Nelson et al. 1976). Many immature fruits can be sorted from mature fruits on the basis of differences in berry size. The sorting can be done on the in-plant cleaning line with a tapered-finger, continuous sizer (Morris et al. 1978, Morris et al. 1974, Morris et al. 1978, Nelson et al. 1978, Nelson et al. 1976). Percentages of mature and immature berries obtained by sorting the berries into small (mostly green and inception) and large (mostly ripe) categories depends upon cultivar and harvest date. The large green fruit that is sorted with the large ripe fruit eventually ends up in the processed product. Research has shown strawberry products containing as much as 50% immature fruit can be utilized in the production of commercially acceptable jam (Table 2). Organoleptic evaluation of jam made from the various maturity mixtures of the mechanically harvested fruit indicated that jam quality increased as the amount of green fruit decreased. However, as much as 50% of green fruit could be used in jam prepared from 'Cardinal', 'Earlibelle', and 'A-5344' to produce a product acceptable to the panel. Jam prepared from up to 50% green fruit of these three cultivars (all with high levels of total anthocyanins yielded products which were comparable in quality to jam prepared from 100% ripe fruit of 'Tioga'. Taste panel evaluation indicated that all products prepared from 'Cardinal', 'Earlibelle', and 'A-5344' were still acceptable after 9 mo of storage at 21^{o} C. Because of the high total anthocyanin content of ripe 'Cardinal', 'Earlibelle', and 'A-5344' berries, it was possible to prepare a jam of acceptable color intensity even when large quantities of immature fruit were used. Later work has shown that strawberry jam made from cultivars having extremely high anthocyanin levels can contain as much as 75% large immature fruit and still be rated acceptable (Spayd and Morris 1981). Immature fruit did reduce color quality of jam but did not influence color loss and discoloration during storage at 2^{o}C, 25^{o}C, and 35^{o}C (Spayd and Morris 1981). Total anthocyanin levels were more important in attaining acceptable color than the percentage of ripe fruit in the jam (Spayd and Morris 1981A, Spayd and Morris 1981B).

Puree is used in the manufacture of these acceptable products that are produced from mechanically harvested fruits (Sistrunk and Morris 1878). The need for decapping the strawberries is eliminated since the calyx can be removed by the screen in the in the pulping machine.

If preserves are to be manufactured, whole fruit is required. Also, frozen strawberries in the whole or sliced form demand a premium price. If machine-harvested strawberries are to be utilized in this market the fruit must be decapped after it has been machine harvested and cleaned. Numerous attempts have been made to develop a decapping machine for strawberries, but a totally successful unit that will handle the volume of fruit desired by the processing industry has not yet been devised. Work is currently underway on this problem at Michigan State University, at the University of Arkansas, in Canada, and by private industry.

Strawberries are highly perishable; however, Morris and Cawthon (1979) have shown that extremely firm-fruited strawberries for processing can be mechanically harvested, properly cleaned and handled, and then held for up to 48 hr at 24^{o}C and for 7 days at 1.7^{o}C without excessive quality loss. Fungicide dips before storage suppress mold growth and reduce loss of soluble solids (Morris and Cawthon, 1979).

Table 2. Effects of Cultivar and Fruit Maturity Mixtures on Sensory Evaluation and Total Anthocyanins of Mechanically Harvested Strawberry Jam (Initially and After 9 mo at 21^{o}C).

Cultivar/ Maturity Mixture[a]	Color intensity[b]		Color acceptance[b]		Flavor[b]		Total Acy (mg/100g)	
	0	9 mo	0	9 mo	0	9 mo	0	9 mo
'Cardinal'								
1/2R, 1/2G	7.5	6.2	7.5	6.5	8.2	7.1	12.1	4.7
3/4R, 1/4G	8.6	7.3	8.2	6.4	8.1	7.2	13.2	5.6
7/8R, 1/8G	8.7	7.2	8.7	6.5	8.2	8.4	15.0	6.5
'Earlibelle'								
1/2R, 1/2G	7.2	7.3	7.4	6.1	6.5	6.9	11.0	5.3
3/4R, 1/4G	8.0	7.2	8.4	6.0	8.0	7.4	15.0	8.5
7/8R, 1/8G	8.8	8.4	8.9	6.9	8.1	7.7	17.2	9.0
'A-5344'								
1/2R, 1/2G	7.7	6.7	7.1	5.2	7.2	7.2	9.9	5.6
3/4R, 1/4G	7.9	7.3	8.3	5.6	7.9	7.4	11.2	5.6
7/8R, 1/8G	8.5	7.2	8.5	6.2	8.2	7.4	13.0	5.9
'Tioga'								
1/2R, 1/2G	3.3	5.0	4.5	4.0	5.3	6.0	3.7	2.5
3/4R, 1/4G	3.8	5.5	5.5	4.4	6.0	6.1	4.4	3.4
7/8R, 1/8G	4.8	5.3	6.3	4.2	7.4	7.6	5.3	4.7
1R, 0G	5.0	6.0	6.8	5.7	7.9	7.3	6.3	6.2

[a]R = large, ripe fruit; G= small, green fruit. Fraction indicates the proportion of each maturity used to prepare product.
[b]Attributes rated by a 10-member panel on a 1-10 scale: 10 = excellent, 5 = acceptable, and 1 = totally unacceptable.

Additional work (Morris et al. 1979A, Morris et al. 1979B) showed that an acetaldehyde atmosphere and a combination of atmospheres and dips are effective in maintaining good color, freedom from browning, and product acceptability of machine-harvested strawberries held for 72 hr at 24^{o}C. Fruit stored in an acetaldehyde atmosphere increased in acidity after 72 hr of storage due to the conversion of acetaldehyde to acetic acid, but acidity returned to near initial levels after 120 hr.

BLUEBERRIES

Commercial harvesters have been used by the blueberry industry since 1966 (Austin and Williamson 1977, Mainland et al. 1975). These over-the-row harvesters shake and dislodge berries from the bush. The fruit is caught in pans and conveyed to the rear of the machine where trash and leaves are removed by high-velocity air.

Austin and Williamson (1977) reported that the amount of ripe rabbiteye blueberries lost on the ground is greater when the berries are harvested by machine than when they are harvested by hand; however, proper pruning of rabbiteye blueberry bushes can increase the efficiency of machine harvesting. Mainland et al. (1971, 1975) reported that marketable fruit of machine-harvested highbush blueberries was from 4 to 44% less than that of the hand-harvested blueberries (Mainland et al. 1975). In addition to fruit being lost on the ground, some green and unripe fruit had to be removed by grading. Machine-harvested fruits in the ripe category were 4 to 32% softer than hand-harvested fruit (Mainland et al. 1971, Mainland et al. 1975).

Sorting and grading machine-harvested fruit on a commercial cleaning line further soften the berries and cause more decay in storage (Mainland et al. 1971, Mainland et al. 1975). New methods of sorting blueberries are necessary for machine-harvesting to be totally successful. Several techniques have been developed (Ballinger and Kushman 1971, Bower and Rohrbach 1974, Hamann et al. 1973, McClure et al. 1973, Rohrbach et al. 1973). These techniques include sizing, fiber optical light measurement, vibration and density sorting. Sizing has not been an effective means of sorting for quality since this method does not discriminate between ripe and overripe fruit (Ballinger and Kushman 1971). The fiber optical light method uses the anthocyanin content of the berries as a means of separation (McClure et al. 1973, Rohrbach et al. 1973). Mature berries have higher anthocyanin levels than immature berries; thus, this method sorts berries into maturity classes (green, ripe, and overripe). The low-frequency vibration method separates blueberries on the basis of firmness (Bower and Rohrbach 1974, Hamann et al. 1973). This method separates green (very firm), ripe (firm to soft), and overripe (very soft) berries according to their "bounce". Also, the USDA (Tennes and Burton 1979) has developed a new hydro-handling system for blueberries which is superior to the standard grading line due to removal of a higher percentage of undesirable fruit (green, soft, bruised, etc.).

Decay of machine-harvested blueberries during postharvest holding is perhaps the biggest problem of the industry (Ballinger et al. 1978, Bower and Rohrbach 1974, Burton et al. 1979, Cappellini et al. 1982, Hartung et al. 1979). Cappellini et al. (1982) reported that 15.2% of the blueberries in New York markets were defective, and about 2/3 of this was due to decay. Ballinger et al. (1973) reported that bruising softens berries and increases decay after storage for 7 days at 21°C.

Temperature during storage is a critical factor in the development of decay in blueberries. Ballinger et al. (1978) reported that berries held at 22.7°C developed an unacceptable level of 20% decay within 1 to 5 days; whereas, those held at 1.1°C required 12 to 32 days, depending upon the ripeness of the berries. Fruit with a total soluble solids: acid ratio over 30 (very ripe) should be processed within 24 hr and should not be sold on the fresh market (Ballinger et al. 1978). Blueberries should be stored at 0°C (Bunemann et al. 1957, Hrushka and Kushman 1963). Precooling blueberries to 2°C reduced decay when held for 24 hr at 21°C after a 3-day simulated transit period at 10°C (Hudson and Tietjen 1981). Fungicide sprays and dips, hot fungicide dips, and hot water dips reduced postharvest decay and maintained quality during holding (Burton et al. 1979, Hartung et al. 1979).

The application of the growth regulator ethephon to the bush prior to harvest accelerates color development, abscission, and maturity of blueberries (Eck 1970, Howell et al. 1973, Howell et al. 1976, Ismail 1974). Ethephon reduces the amount of force necessary to dislodge the berries from the bush (Howell et al. 1976); thus, fruit were damaged less during machine harvest and shelf life was increased.

GRAPES FOR JUICE AND WINE

Major developments in juice and wine grape harvest mechanization occurred in the early and mid-1960's (Olmo 1980, Shepardson and Miller 1962, Shepardson et al. 1969, Studer and Olmo 1969) and mechanization was commercially practiced by the late 1960's (Benedict et al. 1971, Daily et al. 1971, Johnson 1977, Marshall et al. 1972). Mechanically harvested grapes can have better quality than hand-harvested grapes when delivered promptly to the processing unit (Johnson 1977, Peterson 1979). However, there are still several inherent problems which lead to quality loss associated with machine harvesting. Quality of machine-harvested grapes is influenced by the following factors: (a) machine; (b) cultivar and production system; (c) harvest temperature and interval between harvesting and processing; (d) material other than grape (MOG); and (e) postharvest handling system.

Machine Effects

Today, many of the commercial harvesters employ the use of "pivotal strikers", which consist of a double bank of flexible horizontal rods that strike and shake the vine to remove fruit. In California, the "trunk shaker" or pulsator harvesting concept is another commonly used method. This method incorporates 2 parallel rails to impart horizontal vibration to the upper trunk and/or cordon. The trunk shaker is only effective in removing fruit in contact with a rigid trunk or cordon, and much less MOG is harvested. Some of the newer machines have combined the 2 principles and reduced the number of horizontal rods. One commercial company refers to its unit as a "pivotal pulsator". Since it operates at a lower speed, this unit results in less leaf removal and vine damage. It has been reported that shorter strokelengths result in more damage to the grapes, but the frequency of the beater does not affect the amount of damage (Ruff and Holmes 1976). Fruit are removed with all harvesting methods as cluster parts or as individually torn berries. Perhaps the major quality problem with mechanically harvested grapes is the fruit damage from the beater rods or slappers and the handling after harvest (Bourne et al. 1963, Christensen et al. 1973, Marshall et al. 1971, Moyer et al. 1961, Shepardson and Miller 1962). The percentage of intact mechanically harvested berries may be as low as 40% (Moyer et al. 1961).

Cultivar and Production System Effects

With certain cultivars that are readily suited for mechanical harvesting (Christensen et al. 1973) (e.g., 'Concord', 'Niagara', 'Flora', 'Thompson Seedless', 'Gewurztraminer' and 'Cabernet Sauvignon') a mechanical harvesting crew will deliver about the same amount of fruit to the processing unit as do hand-harvesting crews. A mechanical harvesting crew may deliver much less fruit to the processor with hard-to-harvest cultivars (e.g., 'Emerald Riesling', 'Grenache', 'Zinfandel' and 'Muscat Canelli') than do hand harvesting crews.

Structure of the cluster framework and its adherence to the vine and to the berries are the main factors determining how easily and in what condition the fruit is removed. Fruit of most cultivars are removed primarily as single berries. This is particularly true of berries with fairly loose attachment. Cultivars with a firm berry attachment and a tough or wiry cluster framework are the most difficult to harvest mechanically. The 'Emerald Riesling' cultivar has berries that are securely held by the internal vascular system ("brush") of the pedicels. The harvester must "juice" the fruit off the vine, leaving the cluster framework and the large, wet brushes behind. The soft, juicy berry texture of 'Semillon', 'Muscat Canelli', and 'Burger' presents harvesting problems because of juice loss during fruit handling. Conversely, the very firm berries of easily harvested 'Tokay' and 'White Malaga' undergo almost no juicing during machine removal (Christensen 1973).

Larger fruit and those harvested later in the season are more susceptible to mechanical damage (Marshall et al. 1971, Moyer et al. 1961). The ease or difficulty of mechanical harvest also depends upon training system, type and condition of the trellising system and wire, and vine vigor.

Because many cultivars of muscadine grape (*Vitis rotundifolia* Mich.) do not ripen uniformly, once-over harvesting removes immature as well as mature berries. The presence of immature fruit is undesirable since it lowers the quality of the processed product. A system for sorting machine-harvested muscadine grapes into maturity classes has been developed at the University of Arkansas (Lanier and Morris 1979). This system utilizes brine solutions of different strengths to separate the grapes according to specific gravity. Thus, ripe berries with good quality can be separated rapidly and inexpensively from immature berries with poor quality.

Muscadine grapes are also unique in that an abscission layer forms as the berries mature. This layer is so complete within some cultivars that fully ripe fruit will drop in advance of the mechanical harvester's collecting mechanism. The University of Arkansas designed an extended collecting unit, which is adaptable to the front of any conventional commercial harvester, that prevents the loss of these over mature fruits.

Effects of Harvest Temperature and Interval Between Harvesting and Processing.

A considerable time delay between mechanical harvesting and delivery to the processing plant can result in increased enzymatic activity and browning, oxidation (i.e., loss of color), and development of off-flavors and microbial growth (Bourne et al. 1963, Chistensen et al. 1973, Marshall et al. 1971, Marshall et al. 1972, Peterson 1979, Splittstoesser et al. 1974). Temperature from the time of harvest to the time of processing probably influences the quality of machine-harvested grapes more than any other factor (Benedict et al. 1968A, Benedict et al. 1971, Benedict et al. 19688, Benedict et al. 1973, Jones et al. 1968, Marshall et al. 1971, Marshall et al. 1972, Morris et al. 1979, Morris et al. 1972, Morris et al. 1973, O'Brien and Studer 1977, Peterson 1979). Grapes placed in pallet boxes after harvest do not increase in temperature for 72 hr (Morris et al. 1979). The initial temperature of the grapes at harvest governs the storage temperature, regardless of the external air temperature. High temperature at harvest in combination with a delay in processing leads to rapid deterioration of grape juice quality (Benedict et al. 1968A, Benedict et al. 19688, Benedict et al. 1973, Jones et al. 1969, Morris et al. 1979, Morris et al. 1973). Grapes harvested when fruit temperature is high (Ca. 35^{o}C) produce high levels of alcohol and acetic acid, both of which are signs of microbial spoilage, and have poor color (Morris et al. 1973). The alcohol and acetic acid contents of mechanically harvested grapes begin to accumulate 12 hr from the time of harvest if grape temperature at harvest is as high as 29^{o}C. The alcohol and acetic acid contents increase rapidly after 18 hr of holding at 29°C or 24 hr at 24°C. Decreases in soluble solids, flavor, and color quality parallel the increases in alcohol and acetic acid (Benedict et al. 1968A, Benedict et al. 1968B, Morris et al. 1979). Off flavors in the processed juice product can be expected when alcohol levels reach 0.25%.

High temperatures (above 25°C) of grapes at harvest are usually not a problem in cool areas (Bourne et al. 1963, Jones et al. 1969, Marshall et al. 1971, Moyer et al. 1961), but grapes in hot areas (such as the San Joaquin Valley of California and in the southern United States) should be harvested during cool periods of the day or at night to avert quality loss (Benedict et al. 1968B, Benedict et al. 1973, Jones et al. 1969, Morris et al. 1979).

MOG Effect

Machine-harvested grapes may contain a rather high percentage of MOG such as bark, canes, leaves, and petioles (Marshall 1977, Marshall et al. 1971, Petrucci and Siegfried 1976). All of this material may not be removed and may eventually reach the processed products. Cultivars which are more difficult to harvest usually contain more MOG than do easily harvested cultivars (Marshall et al. 1971). MOG may be reduced by cultural practices (Petrucci and Siegfried 1976) or improved cleaning machinery (Marshall 1977). In mechanically harvested vineyards trellised on wooden stakes it is also imperative that a magnet be installed on the machine's discharge conveyor to collect staples and other iron-containing objects.

Effect of Postharvest Handling System

The addition of sulfur dioxide to machine-harvested grapes has been shown to decrease quality loss during holding (Benedict et al. 1973 Bourne et al. 1963 Christensen 1973, Morris et al. 1979, Morris et al. 1972 Morris et al. 1973, Nelson and Ahmedullah 1972, O'Brien and Studer 1977). Addition of 80 to 160 ppm sulfur dioxide immediately after harvest slowed postharvest deterioration of machine-harvested grapes by delaying alcohol accumulation and loss of soluble solids for 24 hr when held at 35°C (Morris et al. 1979). Also, sulfur dioxide discourages bacterial spoilage that might be expected at high fruit temperatures over a long period; it also serves as an antioxidant to prevent juice browning. Production of alcohol in fruit harvested and held at 35°C increased after 6 hr holding and exceeded 2% after 42 hr unless treated with 80 ppm SO_2 (Fig. 1). Use of 80 ppm reduced alcohol production of samples harvested and held at 35°C to the level of untreated control samples at 24°C. It was possible to maintain alcohol content below 0.25% (0.25% is the level of alcohol development where taste panel members began to detect off-flavors) for up to 42 hr if 80 ppm SO_2 was added to grapes harvested at cool temperatures (24°C) Fig. 1).

The type of containers used for hauling the grapes to the processing unit can influence product quality. Initially, .91-MT (1-ton) capacity wooden bins with food-grade plastic liners were used to accommodate the fruit; however, many operations on the West coast have shifted to a 3.6- to 4.5-MT (4-to 5-ton) capacity hydraulic, self-dumping vineyard gondola that dumps the harvested grapes from the vineyard into bulk tank trucks which are hydraulically dumped at the processing plant. These bulk collection units have not reduced the quality of the processed product (Marshall et al. 1971, Marshall et al. 1972, O'Brien and Studer 1977).

There is currently a trend toward crushing the grapes in the field as soon as the fruit are discharged from the harvester and transporting the juice to the processing unit. O'Brien and Studer (1977) developed a closed gondola tank for collecting crushed grapes and juice from the harvester with a stemmer-crusher. This system is effective in controlling microbial growth and oxidation since it permits injection of carbon dioxide, nitrogen, or sulfur dioxide into the tank.

Cost and convenience of the various hauling systems have been major contributing factors in determining the system selected by a given processor; however, additional research is needed in this area.

GUIDELINES FOR OPERATORS OF COMMERCIAL HARVESTERS IN ARKANSAS

The following guidelines were developed by our grape research group at the University of Arkansas in cooperation with the commercial grape-processing industry to maintain or improve the quality of machine-harvested grapes: (1) Select the proper rpm of the shaking mechanism or strikers and the proper ground speed for the harvester for each cultivar and crop load situation (the importance of proper machine adjustments and operation cannot be overemphasized). (2) Establish a time limitation from harvesting to processing plant delivery. The time limitation will depend on cultivar (2 to 4 hr. for grapes used for premium white wines and 8 to 14 hr for grapes used for red wine and grape juice).

Other factors to be considered are fruit temperature, SO_2 usage, and quality standards required for the final product: (1) When harvesting under high temperature conditions, apply SO_2 at the rate of 100 ppm as the grapes pass over the final delivery conveyor. (2) Prepare vineyard to eliminate MOG problems. This may require mechanically trimming low-hanging canes that interfere with harvest, removing bird nests, removing tall weeds, preparing a smooth surface to the vineyard floor, and stopping all cultivation in sufficient time prior to harvest to minimize dusty conditions during harvesting. (3) Inspect the vineyard for foliar-feeding insects and if necessary apply required special sprays sufficiently ahead of harvest. (4) Provide a bin or conveyor inspector as part of the harvesting crew. This individual would remove MOG; watch for plugging of cleaning fans, for hydraulic leaks and for mechanical failures; monitor the

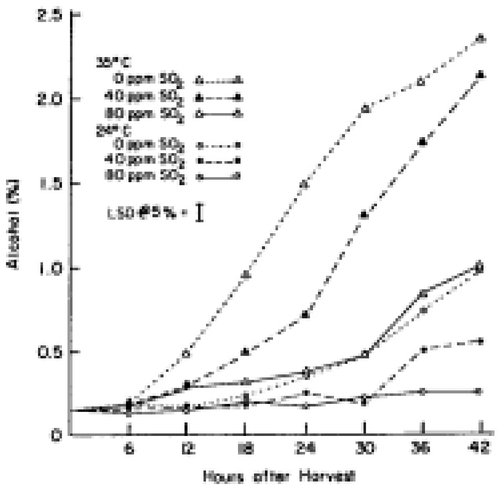

Fig. 1. Interactive effects of fruit temperatures, SO_2 concentration and holding time on alcohol content of 'Concord' grapes. (Means pooled over time of SO_2 application). From Morris et al. 1979.

application of SO_2; etc. (5) Keep harvested grapes covered at all times and require a complete washing of delivery bins or containers after the grapes are dumped at the processing plant or winery. (6) Wash and clean mechanical harvesters thoroughly with an approved detergent-sanitizer at the end of each 8-to 10-hr operating shift (under some conditions a complete high-pressure water rinse may be required during the operating shift).

The most success in small fruit and grape harvest mechanization has occurred using totally integrated systems that include proper cultivars, cultural programs, harvesting principles, postharvest handling, and product utilization. Research efforts must continue to refine and improve the weak areas of each of these systems.

It is possible to selectively harvest and produce a final product with some small fruits such as brambles that are equivalent and often superior to hand-harvested fruits in quality. Extensive research on handling and product utilization has been required in order to make mechanical harvesting feasible. Also, mechanical harvesting of grapes has resulted in a final product quality that is either superior, comparable or inferior to hand-harvested fruit, depending on how the harvesting system is managed.

Harvesting practices and handling of all small fruit crops before, during, and after harvest will depend to a large extent upon the final destination. Blueberries represent a small fruit crop that is currently being mechanically harvested and sold on the fresh market. Future research and developments on all small fruit crops must provide for less damage, more selectivity, and less unwanted plant debris which may allow for some of these crops to be utilized by the fresh market. Additional research and development must continue with emphasis on development of totally integrated systems.

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