

PHYSIOLOGICAL AND HISTOLOGICAL
CHANGES IN CHERRY FRUIT
(PRUNUS CERASUS L., CV.
MONTMORENCY) DURING MECHANICAL
HARVESTING, HANDLING, AND
PROCESSING

Thesis for the Degree of Ph. D.
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This is to certify that the

thesis entitled

PHYSIOLOGICAL AND HISTOLOGICAL CHANGES IN
CHERRY FRUIT (PRUNUS CERASUS L. CV. MONTMORENCY)
DURING MECHANICAL HARVESTING, HANDLING, AND PROCESSING

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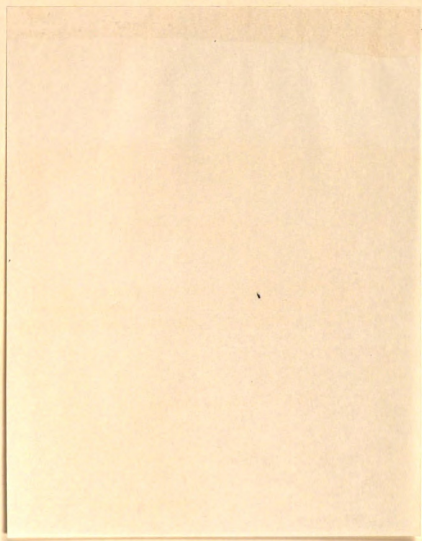
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has been accepted towards fulfillment
of the requirements for

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Carlton E. Mitchell
Major professor

Date February 18, 1969



PHYSIOLOGICAL AND MECHANICAL ASSESSMENT OF
CHERRY FRUIT QUALITY
MONTGOMERY, TENNESSEE
HARVESTING, 1966
AND 1967

Calvin E. Smith

In 1966 and 1967, cherries were harvested at various stations during the harvest period. The effect of harvesting procedures and equipment on the quality of the fruit was influenced the grade of the fruit. The fruit was picked and mechanically harvested. The fruit was sorted for 4, 8, 12, and 24-crown sizes. The fruit was sorted within the fruit.

Based on the results of the study, the grade of mechanically harvested fruit was found to be directly related to the grade of the fruit. However, the procedure of sorting the fruit after harvest, cherries after 12-crown sizes, was found to be marked by red pigmentation.

There was a significant difference in the grade of fruit during the harvest period. The fruit was sorted with the same equipment. The fruit was sorted with the same equipment.

There was an increase in scald when mechanically harvested cherries were soaked for 4, 8, and 12 hours. However, the scald was not evident until the cherries were bleached. Increase in scald was not significant for the

ABSTRACT

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AND PROCESSING

By

Calvin Eugene Arnold

In 1966 and 1967 cherries were collected at various stations during the harvesting, handling, and processing procedures and evaluated for changes that might influence the grade of the processed product. Hand-picked and mechanically harvested cherries were soaked for 4, 8, 12, and 24-hours in 1968 to evaluate changes within the fruit.

Based on percent blemished fresh fruit, the fresh grade of mechanically harvested cherries did not accurately reflect the grade of the processed product. However, the processed grade was reflected by grading the cherries after SO_2 bleaching, which revealed bruises masked by red pigment.

There was a gradual increase in percent blemished fruits during mechanical harvesting, handling, and processing with the major increase occurring during the processor soak.

There was an increase in scald when mechanically harvested cherries were soaked for 8 hours and longer. However, the scald was not evident until the cherries were bleached. Increase in scald was not significant for the bleached hand-picked cherries even after a 24-hour soak.

There was a reduction in fruit size after mechanical harvesting and after the processor soak. There was a significant increase in percent soluble solids after mechanical harvesting, however, this was lost during the field soak. There was a second slight but significant drop in percent soluble solids during the processor soak.

Mechanical harvesting reduced flesh firmness. This loss was recovered during the field soak, however, there was a further loss during processing.

There was a significant increase in firmness of mechanically harvested cherries after a 24-hour soak, but length of soak had no significant effect on firmness of hand-picked cherries. During soak the mechanically harvested cherries were always softer than the hand-picked cherries.

Red color was lost from the peel as mechanically harvested cherries moved through the handling and processing procedures with the greatest loss occurring during a 24-hour soak by the processor. However, when comparing mechanically harvested and hand-picked cherries, this loss was not evident for hand-picked cherries, indicating an interaction of bruising and length of soak with change in

peel color.

Respiratory activity was greater for mechanically harvested cherries than for hand-picked. This increased respiratory activity appeared to be related to scald formation.

Microscopic examination indicated that darkened bruises on the epidermis of the cherries occurred prior to mechanical harvesting.

Sections of tissue of scalded cherries showed no crushing or distortion of cells, but the epidermal cells appeared dense, and the cell walls appeared to be thicker than those of non-scalded tissue. Since the cells of scalded tissue did not appear distorted, bruising apparently induced a physiological change or membrane disruption which resulted in discoloration.

Tannins were located primarily in the epidermal region, but during a 24-hour soak there was a slight movement of tannins into the outer cortical cells, with the movement being greater in mechanically harvested cherries than hand-picked. The cellular disruption resulting from bruising by mechanical harvesting possibly aided the movement of tannins inward from the epidermal area.

In this 3-year study, the single defect resulting from mechanical harvesting which reduced the grade of processed sour cherries was scald. Also, the findings revealed that scald was not a factor until the mechanically harvested cherries were soaked longer than 8 hours before processing.

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MONTMORENCY) DURING MECHANICAL
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By

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RESPECTFULLY OBTAINED
TO MY EAGERS
MR. AND MRS. JORDAN JONES
OF GREENSBORO, FLORIDA

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The author is also indebted to Dr. C. M. Harrison, A. E. Kenworthy, L. W. Mericle, and R. F. Sorenson for serving on the guidance committee and for their excellent help and guidance.

RESPECTFULLY DEDICATED

TO MY PARENTS

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MR. AND MRS. ROBERT ARNOLD

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concerned because he buys "A" grade cherries, but the product is frequently a lower grade after processing. Latent bruises within the cherries could be responsible for this loss in quality. Scald present after storage and processing may be the result of bruising during mechanical harvesting. Whittenberger (45) has suggested that the loss in quality may result from the handling and processing procedures used at the processing plant.

Loss in quality of ripe cherries during harvesting, handling, and processing has been discussed by other researchers (6, 7, 28, 32, 44, 45, 50, 51, 52, 53, 54). Much has been learned, yet much remains to be learned. Although the various possible latent injuries which occur prior to the time the cherry takes place in the processing plant are known, the relative contribution of each to the final quality of the processed fruit is not known.

A study was conducted to determine the relative contribution of the various factors responsible for the loss in quality of mechanically harvested fruit. The factors studied were: (1) mechanical harvesting, (2) storage, (3) processing, and (4) distribution.

handling, and processing procedure results in the major loss in quality, and (c) compare fruits harvested and handled in different ways to determine possible tissue, cell and chemical differences which could account for loss in quality. Since the advent of mechanical harvesting, growers

INTRODUCTION

and processors have been concerned about the reduction in grade of processed sour cherries. The processor is concerned because he buys "A" grade cherries, but the product is frequently a lower grade after processing. Latent bruises within the cherries could be responsible for this loss in quality. Scald present after storage and processing may be the result of bruising during mechanical harvesting. Whittenberger (65) has reported that the loss in quality may result from the handling and processing procedures used at the processing plant.

Loss in quality of sour cherries during harvesting, handling, and processing has been studied by other researchers (6, 7, 20, 21, 33, 34, 40, 41, 62, 63). Much has been learned, yet many questions are still unanswered including possible latent injury within the fruit, where the injury takes place in harvesting, handling and processing, and the contribution of various types of injury in lowering the grade of the processed product.

A study was initiated in 1966 to (a) determine the factors responsible for loss in quality of fresh and processed fruit, (b) determine what phase(s) of the harvesting,

handling, and processing procedure results in the major loss in quality, and (c) compare fruits harvested and handled in different ways to determine possible tissue, cell and chemical differences which could account for loss in quality.

Development of the Sour Cherry Fruit

The growth and development of the sour cherry fruit has been studied by Tukey et al. (35, 36, 37), and Bradbury (19) while Esau (17) gave a good description of the sour cherry fruit.

According to Esau (17), the cherry fruit was composed of the exocarp or skin, the fleshy mesocarp, and the stony endocarp. The exocarp includes the epidermis and several layers of collenchyma cells. The fleshy mesocarp consisted of loosely packed parenchyma cells which increase in size from the periphery toward the center. In the same direction, the cells changed in shape from oval, with the largest diameter parallel to the surface of the fruit, to cylindrical, with the largest diameter in the radial direction.

There is a characteristic change in the exocarp (18) a rapid increase in size of the epidermis and collenchyma, a delayed increase in size of the mesocarp, and a delayed increase in size of the endocarp. The endocarp is a stony, sclerotized layer which is present from mid-season but which increases in thickness and changes to the stony endocarp at the end of the season.

REVIEW OF LITERATURE

Development of the Sour Cherry Fruit

The growth and development of the sour cherry fruit has been studied by Tukey et al. (55, 56, 57), and Bradbury (10) while Esau (17) gave a good description of the sour cherry fruit.

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There are three stages of pericarp development (55): a rapid increase in size following fertilization (stage I), a delayed increase during mid-season in which the stony endocarp enlarges (stage II), and a second increase in size from mid-season until fruit ripening (stage III). The change to the period of delayed growth was abrupt and the

duration of this period (stage II), 10 to 12 days for the Montmorency cherry, was independent of the rate of growth and the size attained during this period. The increase in size during stage I was primarily due to cell division, whereas the increase during stage III was primarily due to cell enlargement.

Tukey and Young (56) stated that two vascular bundles lie at either side of the ventral suture and adjacent to the ovarian cavity. A ring of vascular bundles, generally 18 to 20 in number, extended through the fleshy mesocarp in a direction parallel with the central axis. At maturity, the vascular bundles ramified throughout the fleshy mesocarp to give a skeletal network of conductive tissue. The epidermis was described as a single row of cells covered externally by a cuticle.

According to Nitsch (44) a fruit consists of cells with walls, protoplasm, and vacuoles; and, up to the time of anthesis, the protoplasm makes up the bulk of fruit tissues. As cell division ceased and cell enlargement began, the relative volume of the protoplasmic fraction tended to decrease, while the cell wall and the vacuole gained in importance.

Frey-Wyssling (19) in discussing plant cell walls stated that, ontogenetically, two different layers could be distinguished, the primary and secondary wall. The primary wall was thin while the secondary wall often became thicker

with three or more layers. In the mature cell, the primary wall may be overlooked in view of the striking secondary wall, but physiologically the primary wall was important because it was the envelope of the young cell during proto-plast development. When the cell reached its final size the secondary layers were deposited. Chemically, there was no fundamental difference between the two walls with both consisting of cellulose, hemicellulose, and pectins. According to Nitsch (44), as cell enlargement proceeded, individual cells tended to become spherical and loosened from each other. Concomitantly intercellular spaces were formed and lined with relatively thick pectin layers. He described fruit maturation as follows:

"When maturation commences, the protopectin content of the fruit decreases and pectin is formed. The continuous phase of the young primary wall consists of protopectin in which cellulose strands form only an open-lace pattern. As fruit cells enlarge, the volume of the vacuoles increases steadily, being correlated with a large uptake of water. In addition to water, the vacuoles of fruits contain many other compounds such as tannins and pigments."

Esau (17) stated that tannins frequently accumulate in the epidermis and vascular bundles of fruits.

Taylor and Mitchell (53) reported that the average soluble solids, total soluble solids, and sugar content of cherry fruits increased significantly as the harvest period progressed. Spencer (51) observed that the most obvious changes during fruit ripening were alterations in pigments, texture, and flavoring components, but underlying these

may be changes in hormonal levels, respiration, and cellular organization. of the harvested fruit, and thus, soluble solids. Color, size and soluble solids of the sour cherry are three of the measurable parameters involved in the quality of the processed product. According to Tukey et al. (57), temperature had an influence on ultimate cherry size, color, and sugar content. Cherries developing at high temperatures were small, lacked characteristic red color, and were low in sugar. When the fruits started to color, the under-color green changed to a pale yellow and finally to a light gold at full ripeness. This change was independent of sunlight effects. In sour cherries this change was masked by red color development in the epidermal cells of the skin. Red anthocyanin development was dependent on temperature, while light apparently had little, if any, direct action on this phenomenon. The longer a cherry was left on the tree, the redder it became, and the accumulation of sugar was directly related to anthocyanin development. Spencer (51) felt that color changes in ripening fruit involved chlorophyll destruction and/or qualitative and quantitative alterations in other pigments.

Tukey et al. (57), indicated that fruit size and flesh firmness were unreliable indexes of maturity, while percent soluble solids was found to be the most reliable index for cherries used for processing. Taylor and Mitchell (54) reported that the type of spray chemicals

used for pest control had a significant effect on the soluble solids content of the harvested fruit, and thus, soluble solids alone could not be used as an index of maturity.

Scald Formation

Scald is commonly referred to as discoloration (browning) of cherry fruits due to adverse condition(s). More specifically, scald is the loss of red pigment from the peel of the cherry (35, 38). Some of the pigment moved into the pulp beneath the peel or into the soak water. Correspondingly, LaBelle (35, 38) and Whittenberger (67, 69) reported that pigments were lost from the peel of a previously bruised area of the fruit resulting in a mottled appearance. Whittenberger (67) stated that when cherries were bruised and then soaked, loss of red pigment from the peel in the bruised area was noticeable within 4 to 5 hours. These same areas of the peel turned brown along with the tissue beneath. LaBelle (35, 38) and Yeatman (71) believed this browning to be due to enzymatic oxidation which normally follows cellular disruption. Floate (18) and LaBelle (34) believed that larger and softer fruits were the ones that bruised and scalded most easily.

It has been generally accepted that mechanical harvesting causes more bruising than hand-picking (5, 20, 34, 64, 68), even though tests conducted in New York in 1959 showed that bruising was no worse from mechanical harvesting

than from hand harvesting (33). This conclusion resulted from counts of bruised fruits and from scald which developed during soaking.

LaBelle (34) noted that one source of defective cherries existed quite apart from damage done to the fruit during harvest. He indicated that cherries on the tree which had been damaged by wind-whip, limb-rub, sun-scald, brown rot, or shriveling were shaken down at least as easily as good cherries. Hence, the mechanically harvested cherries had on the average more defects than hand-picked cherries which are somewhat selected.

Bruising is not limited to harvesting operations but may occur during handling and movement through the processing procedure. The recurrent bruising can cause a considerable increase in degree of scalding (63, 65).

Wax sprays have been applied to cherries on the tree in an effort to improve size and quality. Swingle (52) found that cherries from the trees sprayed with wax were considerably larger but there was no observable improvement in quality after soaking at the processing plant.

Various factors have been shown to affect scalding. Many researchers (15, 21, 38, 43, 68) have reported that scalding increased as temperature increased.

In addition to temperature, the length of soak has been reported to affect scalding (35, 38). Soaking may provide a means of cooling and storing large volumes of

fresh cherries, but research (35, 38) has indicated that soaking longer than 8 to 12 hours increased the incidence of scald, even at temperatures as low as 50 F. The effects of temperature and length of soak became very apparent in frozen cherries (35, 38, 40, 41, 42, 67).

Studies have been conducted on the physical and chemical changes involved in scald formation. Pollack (50) indicated that scald was due to a lack of oxygen or to the liberation or accumulation of toxic substances that occurred as a result of an inadequate oxygen supply. Apple scald was believed to be due to a lack of aeration (46). Pollack (50) observed scald formation on bruised cherries at a low oxygen concentration and also on bruised cherries in aerated water. Unbruised cherries at low oxygen concentrations did not scald, thus indicating that bruising and the subsequent disruption of the normal respiratory system, was the primary factor in scald formation.

Several workers (35, 43, 67) have reported that both the loss of pigments from the peel and the subsequent browning involved enzymatic reactions. The bruising, in turn, caused disruption of the cells of the peel containing the anthocyanins. Wagenknecht (61) further reported that the anthocyanase participated in the early stages of scald through destruction of anthocyanin pigments. He isolated two anthocyanins from the sour cherry, cyanidin-3-rhamnogluco-
side and cyanidin-3-diglucoside. Work by Yang (70)

indicated that anthocyanase was specific and acted only on the anthocyanin pigments, and the action of anthocyanase was rapid at room temperature. Wagenknecht (61) further reported that the action of anthocyanase required oxygen. According to Ulrich (58), the browning associated with open-scalding seemed to be due to the activity of polyphenol-oxidase in the presence of O-diphenols and oxygen. He reasoned that in the protoplasm of an actively respiring cell, the oxidation-reduction potential was low enough to prevent the accumulation of oxidized phenols, whereas in damaged tissue, the phenol was probably oxidized faster or reduced slower than in the intact tissue. In the living cells the phenols may not be able to react because of their location in vacuoles, while the oxidases were situated in the protoplasm.

According to Spencer (51), during the final stages of senescence, changes in membrane permeability probably occur and substances such as phenols enter the cytoplasm in abnormally large quantities from the vacuole. Pentzer (46) indicated that the phenolic content of the skin of apples decreased with scald development, indicating that the brown color was formed by the action of enzymes on phenolic compounds. Daravingas (14) reported that anthocyanins were quite unstable chemically, both in solution and in cellular media, and could easily change from their characteristic natural red color to the undesirable brown compounds.

Bogorad (9) stated that anthocyanins were probably the substances most commonly responsible for the reactions in plant tissues attributed to tannins.

Research with the sweet cherry by Hartman (27) indicated there was a decrease in astringency during ripening and the change in tannins and pigments seemed to be closely related to the changes in astringency which were detectable by taste as the fruit ripened. Climate has been shown by Guadagni (24) to have an effect on tannin content in the peach. In general, the area having the warmest and clearest weather produced peaches of the lowest tannin while the cooler, cloudy areas produced fruits with a higher tannin content. There was a significant difference in astringency of peaches grown in areas which caused the lowest and highest accumulation of tannins.

Changes in Firmness

The mechanism or mechanisms responsible for fruit softening are not fully understood, however, there is positive evidence that changes in pectic substances are important (23, 25, 51). Hansen (25) and Spencer (51) have demonstrated that pectic changes during maturation and ripening involved more than a simple change from water insoluble to water soluble fractions. Degree of esterification, molecular chain length, spatial configuration and complexity of side chain structure influenced the solubility and gelling

properties (25, 51, 70). According to Spencer (51), pectin esterase occurred universally in fruits and its activity has been shown to be greater in ripe than in unripe fruits. Gee (23) indicated that the degree of esterification did not increase until the fruit approached full size and with the onset of ripening, esterification increased to virtually 100 percent, but decreased as the fruit softened.

Sour cherries are commercially soaked in cool water (45 to 60 F) previous to processing to promote firming. The firming action has been commonly associated with low temperature. In 1920, Hawkins et al. (28) reported that cooling Montmorency cherries increased their resistance to puncture. Their explanation was that: (a) the surface of the fruit might be covered with a wax which softened at the higher temperature but became harder and more resistant when cooled, (b) the walls of the external cells may have a lower coefficient of expansion than their contents. If this were the case, at higher temperatures the walls would be under greater strain and would therefore puncture more easily. In 1932, Allen (1) stated that stone fruits held at field temperature after harvesting soften rapidly. He suggested chilling the fruit after harvesting to promote firming. However, recent work has shown firming of sour cherries to be primarily time dependent (tissue aging) and not temperature dependent (33, 39, 64). Thus, the major effect of chilling in the soak water was to reduce the amount of

scald, which was temperature dependent. According to LaBelle (33), soaking in water reduced crushing and had the added effect of permitting the cherry to take up water and become more turgid, but had nothing to do with the desired toughening of the cherry flesh.

Parker et al. (45) have shown that there was a definite relationship between bruising and firming in that severely bruised cherries had a greater increase in firmness during soak than less severely bruised cherries. They also reported that firmness of unbruised cherries remained relatively constant during storage. LaBelle et al. (39) reported that when rebruising followed firming, the cherry made a second recovery to an even higher level of firmness.

The firming or toughening of cherries in the interval between picking and pitting has been ascribed to an actual repair or recovery of the bruised tissue (37). This repair was further described by LaBelle (37) and Whittenberger (62) as a strengthening of the intercellular cement and a thickening of cell walls. LaBelle (36) found that increased turgidity helped cherries pit cleanly, but did not, by itself, prevent excessive juice loss nor flabbiness in the final product. Thus, he stated that physiological firming was of more consequence than increased turgidity and being the slower process, physiological toughening controlled the required length of the firming period.

Even if Research in 1957 by Gee (22) indicated that frozen Montmorency cherries toughened when stored at 20 F or higher, but were stable at 10 F. This toughening did not appear to be related to the sugar treatment of the cherries. He stated that all samples exhibited a drop in carbonmethoxyls after storage at 20 F or higher and this drop in esterification was accompanied by an increase in toughness as measured by a tenderometer. As the temperature increased, the rate of toughening increased. Gee suggested that a change in texture may be attributed to an enzymatic deesterification and cross-linking of calcium and pectin carboxyl groups if the cherries were not frozen.

Excellent work by Buch et al. (11) indicated that cherries allowed to stand before being canned, either with or without having been previously bruised, were much firmer after canning than were similar cherries canned immediately after harvest. He found that the pectin was apparently unchanged in chain length or degree of esterification. Histological examination of the tissue showed that the cell walls of the aged cherries were more rigid and less easily separated from each other than were the cell walls of cherries canned immediately after harvest. There appeared to be no relation between firmness and the calcium content of the pectin or remaining insolubles. Also, the weight of insoluble solids remaining after removal of pectin and pectic acid was higher in the firm than in the soft cherries.

Even after he had extracted the pectin with hot hydrochloric acid, the firmed cherries still had definite cell walls, whereas in the soft cherries the cell walls had almost lost their identity. When the pectic acid remaining in the sections was extracted with dilute sodium hydroxide, the cell walls of the soft cherries lost what little cell wall structure they had left, whereas the firmed cherry sections were apparently unchanged. In sections treated with pectin methylesterase and polygalacturonase instead of the chemical treatments to remove pectin and pectic acid, the cell walls of the control cherries disintegrated but the cell walls of firmed cherries remained unchanged. Cell walls of control and firmed cherries differed less when sections were made from raw cherries than from canned cherries. However, when pectin was extracted from the sections, cell walls of the raw cherries reacted like those of extracted canned cherries.

The addition of calcium has been used in an attempt to increase firmness. Whittenberger and Hills (66) stated that cherries soaked in dilute calcium chloride were slightly firmer than those soaked in water. Although bruised cherries increased in firmness when soaked in a calcium solution, they reported that firmness at all stages for the bruised cherries was lower than that of the unbruised cherries.

Changes in Soluble Solids

According to Hills et al. (29) and Whittenberger et al. (66), there may be approximately a 2 percent reduction in soluble solids during a 12 to 24-hour water soak if the cherries were bruised, and a 1 percent reduction if the cherries were unbruised. Hills et al. (29) stated that the greater reduction in bruised cherries was due to leaching and the reduction in unbruised cherries was mainly the result of dilution. Peterson (47) indicated that the passage of water into the soluble solids of the cherry was largely due to osmotic pressure with the skin of the cherry acting as a semi-permeable membrane.

Marshall et al. (42) indicated that loss of soluble solids was accompanied by decreased tartness and flavor in the processed product as well as in the fresh fruit. However, Bedford and Robertson (6) reported that drained weight was not affected by soluble solids. Whittenberger (66) reported that soaking cherries in a calcium solution reduced the loss of soluble solids. The principal pathway for the exchange of substances between the cherries and the soaking medium was the area of tissue exposed by the removal of the stem.

(35) reported that the
branches immediately
and during the
storage

Changes in Respiration

Hansen (25) and Biale (8) included the cherry among the non-climacteric fruits. Biale (8) stated that in non-climacteric fruits there appeared to be a simple gradual decline in respiration throughout maturation and into senescence, and the changes characteristic of ripening often occurred at a constant slow rate. Hansen (25) reported that no appreciable lag period between maturation and ripening could be distinguished in non-climacteric fruits.

Experiments by Pollack and Hills (48) on normal cherry samples, showed that respiratory activity was linear up to 6 hours. In these studies the respiratory quotient rose with increasing maturity and reached a value of 1.95 for the most mature sample. Following bruising, the increase in carbon dioxide evolution greatly exceeded the increase in oxygen utilization. Oxygen consumption increased approximately 50 percent following bruising, whereas the carbon dioxide evolved increased approximately 126 percent. The respiratory quotient rose from an average of 1.80 for the unbruised fruits to 2.47 after bruising.

The increased respiratory activity resulting from bruising may be related to membrane permeability. Hansen (25) reported that permeability changes in cellular membranes immediately preceding or during ripening in fruits, and during senescence in other plant tissues, resulted in

leakage of solutes, increased free space, and liquid clogging of intercellular spaces. Bain and Mercer (4), using pear fruits, showed that cell membranes became more permeable during ripening. They suggested that the respiratory activity of a cell containing excess substrates was controlled by the spatial distribution of enzymes and reactants within the protoplast.

Effect of Nutrients

Kenworthy (32) indicated that average size, size uniformity, and fruit firmness were not consistently related to any one nutrient, but fruit color normally decreased as either potassium or phosphorous increased. Harrington et al. (26) stated that cherry size, color, soluble solids content, and processed yield varied widely according to the year.

Bedford et al. (7) and Moyer (43) demonstrated that trees which received excessive nitrogen usually produced soft cherries which were more easily scalded.

Fruit Abscission

Fruit abscission has become of major concern in mechanical harvesting of cherries. Carns (13) identified the abscission zone as a histologically distinct region at the base of an abscising organ and the "separation layer" as being the transverse layer of cells where separation is

effected. According to Varner (59), abscission of fruits was due to a loss of integrity by membranes resulting from insufficient auxin levels. Varner also stated that a low level of auxin brought about a change in the distribution and activity of pectin methylesterase (and possibly other enzymes) and thereby caused a change in pectin metabolism that contributed toward the changes occurring in abscission.

Esau (17) stated that the abscission zone may be formed by cell division or differentiation without division. According to Varner (60), the specialized cells of the abscission zone developed a separation layer as a result of hydrolytic processes in the cell walls. Carns (13) indicated that in the abscission zone, cells of the ground parenchyma were characteristically smaller, protoplasm is denser, and there were conspicuously fewer intercellular spaces and less fibrous tissue than in comparable portions of the plant. The separation layer developed distal to the abscission zone. Separation was accompanied by dissolution of pectic substances, softening and solubilization of cell walls, and perhaps cytolysis of entire cells. Carns also suggested that the abscission zone appeared to be a region of arrested development where processes of enlargement and differentiation had not proceeded nearly as far as in comparable regions. He concluded that to some extent, the onset of abscission may be considered a resumption of morphological development which resulted from organ maturity,

senescence, or injury in higher plants.

Varner (60) stated that abscission was temperature sensitive, requires oxygen, and was inhibited by respiratory poison. Carns (13) reported that preceding or during abscission, tyloses and wound gum developed and were present both in ground and vascular tissue. Furthermore, starch, amino acids, and other organic constituents tended to accumulate.

Cain (12) stated that the number of fruit on the tree which could be removed by mechanical harvesting decreased as leaf nitrogen increased. Cain also reported that for adequate fruit removal with mechanical harvesting, the average fruit retention force should be less than 400 grams.

1966

In 1966, the Michigan Wildlife Research Station (Buchanan, New York) was established at the Port of New York Harbor, New York. Eight blocks of land were purchased for the purpose of establishing a wildlife refuge.

Fruit Farm, taking into consideration uniformity in size, vegetative vigor, and crop load.

The blocks were selected to give 3 harvest periods

MATERIALS AND METHODS

5 to 7 days apart to determine the effects of maturity.

The first A program was developed in 1966 to find how sour cherries were affected by mechanical harvesting, handling, and processing. To determine the changes in fruit quality, samples were taken before harvest and throughout harvesting, handling, and processing. At each harvest, samples were taken from the grower's field tank containing only cherries from selected trees. The cherries dropped from the conveyor belt of the mechanical harvester directly into the field tank containing water at 50-60 F. The tank was then hauled to the grower's pumping station where the cherries were flushed with a continuous flow of water (50-60 F) for a period of time ranging from 1 to 8 hours. After flushing, the tank was transported to the processing plant.

1966

In 1966, experiments were conducted in southwestern Michigan with the cooperation of Feather's Fruit Farm (Buchanan, Michigan) and Michigan Fruit Cannery, Inc. (Benton Harbor, Michigan).

Eight adjoining trees were selected in each of 3 blocks of mature, bearing sour cherry trees at Feather's

Fruit Farm, taking into consideration uniformity in size, vegetative vigor, and crop load.

The blocks were selected to give 3 harvest periods 5 to 7 days apart to determine the affects of maturity. The first block was harvested July 15, the second on July 22, and the third on July 28. Trees in each block varied in age: block 1--12 years, block 2--10 years, and block 3--40 years.

At each time of harvest, approximately 30 minutes before mechanically harvesting the selected trees, a sample, approximately 1000 grams, of cherries was hand-picked from each of the 8 trees. Immediately following mechanical harvesting, a sample of cherries was collected for each tree at the point where the cherries left the conveyor of the harvester¹ before dropping into the field tank. A fruit sample was then taken at 5 additional points from the composite 1,000-pound lot of cherries, mechanically harvested from the selected trees, as it moved through the handling and processing procedure. After processing, cans of the finished product were removed randomly from the line and held for later laboratory grading.

The locations for fruit sampling were as follows:

<u>Sampling Station</u>	<u>Method of Sampling</u>
1	Fruits were hand-picked randomly from the trees before mechanical harvesting.

¹Shaker-type harvester manufactured by the Friday Tractor Co., Hartford, Michigan.

- 2 Fruits were taken from the conveyor of the mechanical harvester before dropping in the field tanks.
- 3 Fruits were taken from the field tanks when they arrived at the processing plant.
- 4 Fruits were taken while dropping from the rotating scales, just before being flumed into the centrifugal pump.
- 5 Fruits were taken from the holding tank (boot) inside the processing plant after pumping.
- 6 Fruits were taken while dropping into the electric-eye sorter.
- 7 Fruits were taken after the electric-eye sorter.
- 8 Cans of piefilling, the finished product, were taken at the end of the processing procedure.

Each individual sample from stations 1 through 7 was divided into two samples of approximately 500 grams. One sample was placed in a 17 percent sulfur-dioxide brine used for brining sweet cherries. After standing approximately 60 days, the bleached cherries were removed from the brine and boiled for 2 minutes in distilled water in an attempt to reveal blemishes which would have been revealed during processing. The cherries were then graded according to USDA fresh grade standards (2). The cherries were scored as defective when the skin was blemished to the extent that the aggregate area covered by a dark brown scar exceeded the area of a circle $9/32$ of an inch in diameter, or the aggregate of a very dark or black scar exceeded the area of

a circle $3/16$ of an inch in diameter. Cherries with torn shoulders, cracks extending over the shoulder of the cherry, were scored as defective and recorded as percent by weight.

The remaining sample was graded immediately after collection according to USDA standards (2). These cherries were evaluated for size distribution of less than $4/8$ inch, $4/8$ to $5/8$ inch, $5/8$ to $6/8$ inch, $6/8$ to $7/8$ inch, and greater than $7/8$ inch, using a manual sizer with divergent rollers.

Using the sized sample, 25 cherries were selected at random and macerated. A juice aliquot was evaluated for percent soluble solids using a Zeiss hand refractometer. Two refractometer readings were made per juice sample.

The canned samples of processed cherries were graded in December, 1966 in the processor's quality control laboratory by a federal inspector using USDA grade standards (3).

In order to determine possible variations in the nutritional status of the trees used in this study, 25 mid-shoot leaves per tree were picked at random around the tree. These samples were analyzed for nitrogen and potassium by a modified Kjeldahl method and flame spectrophotometry, respectively.

1967

Samples taken in 1966 at various stations in the harvesting, handling, and processing procedures showed a definite loss in quality when compared with hand-picked fruit. The loss was primarily due to surface scald.

Thus, in 1967, experiments were conducted again in southwestern Michigan with the cooperation of Feather's Fruit Farm and Michigan Fruit Cannery, Inc. Similar experiments were conducted in northwestern Michigan with the cooperation of Mr. Joseph Smeltzer (Frankfort, Michigan) and Smeltzer Orchard Company (Frankfort, Michigan) to determine differences between cherries in southwestern and northwestern Michigan.

Six trees were selected in the same 3 blocks used in 1966 at Feather's Fruit Farm, and 6 trees in each of 2 blocks at the Smeltzer orchard. The trees in both blocks at the Smeltzer orchard were approximately 12 years old. For each harvest, the cherries from the selected trees were evaluated at the various sampling stations listed below:

Southwestern Michigan
Sampling Stations

Method of Sampling

- | | |
|---|---|
| 1 | Fruits were hand-picked randomly from the trees before mechanical harvesting. |
| 2 | Fruits were taken from the conveyor of the mechanical harvester before dropping into the field tanks. |

- 3 Fruits were taken from the field tanks when they arrived at the processing plant.
- 4 Fruits were taken while dropping from the rotating scales, just before being flumed into the soak tank.
- 5 Fruits were taken from the conveyor before the destemmer.
- 6 Fruits were taken from the flume after the destemmer.
- 7 Fruits were taken from the holding tank (boot) inside the processing plant.
- 8 Fruits were taken while dropping into the electric-eye sorter.
- 9 Fruits were taken after the electric-eye sorter.
- 10 Sealed cans of the finished product were taken at the end of the processing procedure. Also, cherries were taken before adding sugar or sealing. These cherries were placed in polyethylene bags and frozen.

Northwestern Michigan Sampling Stations

Method of Sampling

- 1 Fruits were hand-picked randomly from the trees before mechanical harvesting.
- 2 Fruits were taken from the conveyor of the mechanical harvester before dropping into the field tanks.
- 3 Fruits were taken from the field tanks when they arrived at the processing plant.
- 4 Fruits were taken while dropping from the rotating scales, just before being flumed into the soak tank.

- 5 Fruits were taken from the processor's soak tank before processing.
- 6 Fruits were taken while dropping into the electric-eye sorter.
- 7 Fruits were taken after the electric-eye sorter.
- 8 Sealed cans of the finished product were taken at the end of the processing procedure. Also, cherries were taken before adding sugar or sealing. These cherries were placed in polyethylene bags and frozen.

Due to a change in the commercial handling procedure at the processing plant in southwestern Michigan, the sampling stations in 1967 were slightly different from those in 1966. However, the first 3 sampling stations remained the same.

The force required to remove the fruit from the tree was measured for 20 cherries selected at random around each tree used in the 1967 study. The force was measured with a Hunter pull-push mechanical force gauge (model L-1000-M)¹, equipped with a claw-adaptor so the cherry could be removed from the stem without apparent injury to the flesh, as shown in Figure 1a.

In 1967, respiratory activity of hand-picked cherries was compared with mechanically harvested cherries for 2 harvest dates in southwestern Michigan. This study was carried out using an oxygen-carbon dioxide gas analyzing

¹Manufactured by Hunter Spring, Div. of Ametek, Inc., Hatfield, Penn.

Figure 1. a. Full-length form of the protein with claw over a cherry.
 b. Dimeric form (L-shaped) shown with a cherry.
 c. Dimeric form (L-shaped) shown with a cherry.

- Figure 1. a. Pull-push force gauge shown with claw over a cherry
- b. Durometer (firmness gauge) shown with plunger pressing against the cheek of a cherry

respirometer (16) referred to

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locally harvested cherries

before the cherries would

Each sample consisted of

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Figure 1

respirometer (16) referred to as APRIL.¹ The hand-picked cherries were carefully picked from the tree and the mechanically harvested cherries were taken from station 2, just before the cherries would have fallen into the field tank. Each sample consisted of approximately 300 grams of cherries. After collecting, the samples were held in air with shading and transported immediately to the respiratory analyzer. Samples were placed in the analyzer approximately 4 hours after collecting. Respiration was measured over 72 hours.

Samples from the tanks and on the processing lines were collected in the same manner as in 1966 except six samples were taken randomly at each of the sampling stations instead of only one sample.

In 1967, 6 cans of the finished product were removed from the line at the end of the processing procedure and 6 cans were removed from the line immediately before the cans were sealed. Cherries from the unsealed cans were placed in polyethylene bags after adding granulated sugar at the rate of 1 part sugar to 5 parts of cherries by volume. The bags were closed and the cherries frozen. In December, 1967 the cherries were removed from the bags, thawed and graded. The grading was done by a USDA inspector

¹Automatic Photosynthetic Respiration Integrating Laboratory, Horticulture Department, Michigan State University.

in the processor's laboratory. The canned cherries were graded at the same time as the frozen cherries.

The samples were graded, sized, evaluated for percent soluble solids. Leaf samples were analyzed as previously indicated for 1966.

In addition, in 1967, 25 cherries were selected at random from each sample taken to determine fruit firmness. One reading was taken on the largest cheek of each cherry with a durometer (type 00)¹ as shown in Figure 1b.

The sample of 25 cherries used to evaluate flesh firmness were used for peel color determinations. This determination was made on a 1/4-inch disc of epidermal tissue from the largest cheek of each of the 25 cherries. The discs were placed in 25 ml of 0.5 percent oxalic acid solution and held at 40 F in the dark until color equalization occurred (one week minimum). The samples were then removed from storage, filtered, with Whatman No. 1 filter paper, and the filtrate brought to 50 ml with 0.5 percent oxalic acid. The absorbance of the pigment solution was determined at 515 mμ with a Beckman DU spectrophotometer.

A histological study in 1967 and 1968 compared fruits harvested and handled in different ways to determine possible tissue, cellular, and chemical differences associated with loss in quality.

¹Manufactured by Shore Instrument and Manufacturing Co., Inc., Jamaica, N. Y.

In addition to the sample of cherries collected at the various sampling stations and fixed in a sulfur-dioxide brine, a second sample of 10 to 12 cherries was placed in the standard FAA killing-fixing solution which consisted of 5 parts formalin, 5 parts glacial acetic acid and 90 parts 70 percent ethanol.

Cherry tissue showing various types of injury were removed from both the FAA and the sulfur-dioxide fixed cherries and carried through the tertiary butyl alcohol dehydration series as described by Johansen (31). After dehydration, the tissue was embedded in tissuemat (Fisher Chemical Co.) with a melting range of 56 to 58 C and sectioned at 20 microns on a rotary microtome. The sections were affixed to the slides with Haupt's adhesive (31) and the paraffin removed with xylene. Sections were not stained but made into permanent mounts for study using phase-contrast microscopy.

A Wild M-20 microscope¹ with a built-in light source, equipped with phase contrast, polarizing discs and photoautomat MKa4 camera attachment² was used for the various microscopic observations and photomicrographs.

¹Product Wild Heerbrugg Ltd., Heerbrugg, Switzerland.

²Ibid.

1968

From the 1967 data, length of soak was a critical factor contributing to scald, the major defect reducing the grade of processed cherries. Thus, in 1968, soak trials were conducted to evaluate the effect of length of soak on the grade of hand-picked and mechanically harvested cherries.

Six trees were selected in each of the 3 blocks of sour cherries used previously at the Feather's Fruit Farm. Also, 6 trees were selected in each of 3 blocks of mature bearing sour cherry trees in the Joseph Smeltzer orchard. The same three blocks of trees were used to determine if time of harvest (maturity) had any influence on the quality of the cherries when interacted with length of soak and method of harvest.

Prior to hand-picking, measurements were made to determine the force required to remove the cherries from individual trees, as described for 1967. Following this, approximately 25 pounds of cherries were hand-picked from each of the trees just before mechanical harvesting. Samples from individual trees provided 6 replications for each block. During the mechanical harvesting operation, a sample of 25 pounds of cherries was also collected for each tree at the point where the cherries left the conveyor of the mechanical harvester and before dropping into the field tank.

Immediately after collecting, the samples were evaluated for soluble solids, peel color, firmness, grade, and size in the same manner as in 1966 and 1967. The samples were then placed in cheesecloth bags and suspended from rods into a soak tank with running water at approximately 55 F as shown in Figure 2.

Following soak times of 4, 8, 12, and 24 hours, a sample of cherries, approximately 500 grams, was carefully taken from each bag and evaluated for firmness, peel color and grade, as in 1966 and 1967. The temperature of the water in the soak tanks was maintained at 55 to 57 F during this study.

Leaf samples were taken from the trees after harvest and analyzed for nitrogen and potassium as in 1966 and 1967.

The date and time of each harvest in 1968 are shown below:

Southwestern Michigan
Harvest Date and Time

First Harvest --- July 8, 1968, 10:00 a.m.
Second Harvest --- July 15, 1968, 3:00 p.m.
Third Harvest --- July 20, 1968, 2:00 p.m.

Northwestern Michigan
Harvest Date and Time

First Harvest --- July 31, 1968, 9:15, a.m.
Second Harvest --- August 1, 1968, 10:45 a.m.
Third Harvest --- August 2, 1968, 10:00 a.m.

In 1968, cherries from the sulfur-dioxide sample were evaluated microscopically for anatomical variations

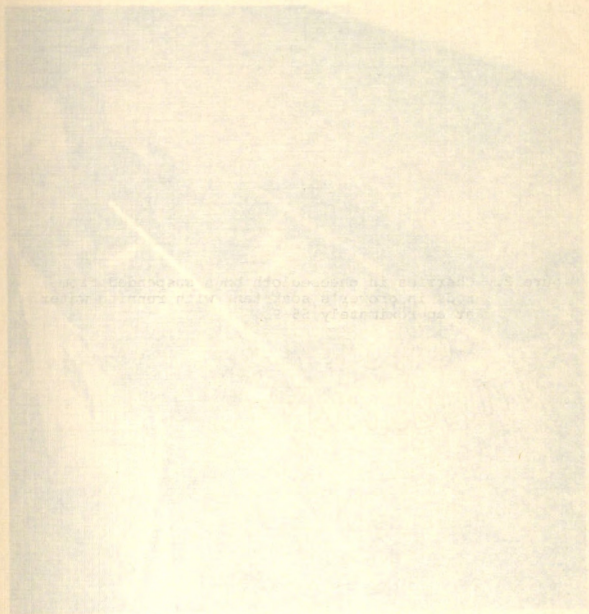


Figure 2. Cherries in cheesecloth bags suspended from rods in grower's soak tank with running water at approximately 55 F

resulting from methanol
tissue was prepared for



Figure 2

resulting from method of harvest and length of soak. The tissue was prepared for microscopic study in the same manner as in 1967. In addition, 4 to 6 cherries from each soak period, both hand-picked and mechanically harvested, were placed in a ferrous sulfate, tannin-staining fixative solution consisting of 10% formalin and 2% ferrous sulfate (30).

Tissue sections of these cherries were prepared for microscopic examination.

Statistical Analysis

The field experiments were set-up in a double split-plot design which was analyzed using Analysis of Variance. When significance was found within a variable, the statistical significance between the means was determined by the Duncan Multiple Range Test. Also, significant interactions were plotted. All statistical calculations were performed at the M.S.U. Computer Center.

RESULTS AND DISCUSSION

The study undertaken in 1966 was of an exploratory nature to determine if any one of the procedures of harvesting, handling, and processing might have a predominant influence on the quality of processed sour cherries. Because no clear trends developed from the 1966 findings, more detailed studies were carried out in 1967, again evaluating the various steps of harvesting, handling, and processing in the hope of finding a possible lead to explain the loss in quality of the fresh product after processing. The study was expanded to determine histologically the nature of the injury to the fruits. In 1967, length of soak of mechanically harvested cherries before processing was found to be critical. This variable was incorporated into the 1968 comparison of hand-picked and mechanically harvested cherries.

Percent blemished fruits.--The changes in percent blemished fruits during harvesting, handling, and processing in 1966 are shown in Table 1. The samples taken at each station were from the same 1000-pound lot of cherries.

Because the differences in percent blemished fruits were between sampling stations rather than date of harvest, the data are presented as an average of the 3 harvests.

Table 1.--Percent blemished fresh and bleached cherries during harvesting, handling, and processing. Average of 3 harvests. Southwestern Michigan, 1966

Sampling Stations	Percent Blemished Fruits ¹	
	Fresh	Bleached
1. Hand-picked before mechanical harvesting -----	7.6a	5.4a
2. Dropping from mechanical harvester -----	9.4a	22.7 b
3. Field tanks when they arrive at processing plant -----	10.0a	23.0 b
4. Dropping from rotating scales ----- (Centrifugal pump)	9.9a	27.2 b
5. Holding tank (boot) inside plant -----	13.1a	40.1 c
6. Dropping into electric-eye sorter -----	12.9a	41.3 c
7. After electric-eye sorter ----	12.7a	37.8 c

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

The blemishes in the hand-picked and the mechanical harvested samples of unbleached fruits immediately after harvesting were due to wind-whip on the tree. However, comparing the bleached cherries of station 2 with those of station 1, the larger number of blemishes of the mechanically harvested samples was due to bruises masked by red pigment before bleaching.

The next large change in percent blemished fruits was immediately after pumping the cherries to the water boot (station 5) in the processing plant. This injury undoubtedly occurred in the rough handling of the fruit going through the pump. The pump was removed from the line in 1967, and replaced by a flume transport system.

In 1966, the processed grade of cherries canned as pie-filling showed no consistent correlation with the percent of blemished fresh or bleached cherries as delivered to the processing plant. The major factor lowering the grade of the canned cherries was lack of red color. The lack of red color was due to scald resulting from bruising in the centrifugal pump.

The date of harvest in 1967 appeared to have no marked effect on the percent of blemished fresh or bleached cherries other than an increase for the third harvest which was due to wind-whip (Table 2).

Table 2.--Average percent blemished fresh and bleached cherries during harvesting, handling, and processing as influenced by date of harvest. Southwestern Michigan, 1967

Harvest		Percent Blemished Fruits ¹	
No.	Date	Fresh	Bleached
First	7/16	9.5a	66.1a
Second	7/20	9.6a	69.3a
Third	7/24	14.7 b	85.8 b

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

In 1967, the percent of blemished fresh cherries from the southwestern Michigan orchard did not change significantly as the cherries were mechanically harvested, handled, and processed as shown for stations 1 through 9 (Table 3). However, after bleaching the percent of blemished fruits was much greater, due to scalding which increased significantly reaching 100 percent after soaking for 20 hours at the processing plant before going to the destemmer (station 5). Bleaching revealed again bruises masked by the red pigment of the unbleached cherries. Thus, the unbleached cherries were as severely bruised as the bleached cherries but the bruises were not visible.

In 1967 the percentage blemished fresh cherries was not reflected in the processed grade of either cherries canned in water or as pie-filling. However, after bleaching (Table 3), it was evident that the processed product would be of very low quality. The processed grade was very low due to lack of red color and firmness. The low grade was also true for frozen cherries.

There was no significant difference in fresh or bleached grade of the mechanically harvested, handled, and processed cherries between the 2 harvests in northwestern Michigan, thus, the percent blemished fruit was averaged (Table 4).

The fresh grade of cherries in northwestern Michigan showed no significant change during mechanical harvesting,

Table 3.--Percent blemished fresh and bleached cherries during harvesting, handling, and processing. Average of 3 harvests. Southwestern Michigan, 1967

Sampling Stations	Percent Blemished Fruits ¹	
	Fresh	Bleached
1. Hand-picked before mechanical harvesting -----	10.0a	15.7a
2. Dropping from mechanical harvester -----	11.3a	33.9 b
3. Field tanks when they arrive at processing plant -----	10.6a	52.9 c
4. Dropping from rotating scales -----	12.1a	61.9 c
(Processor soak)		
5. Belt before destemmer -----	10.8a	99.9 d
6. Flume after destemmer -----	11.2a	99.6 d
7. Holding tank inside plant ----	10.6a	100.0 d
8. Dropping into electric-eye sorter -----	11.8a	100.0 d
9. After electric-eye sorter ----	12.3a	100.0 d

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

handling, and processing (Table 4). However, when bleached, the amount of blemish (scald) increased significantly, but there was not a significant increase in scald during the 4 hour processor soak (station 5) in contrast to the significant increase in southwestern Michigan with a 20 hour soak, station 5 in Table 3.

Table 4.--Percent blemished fresh and bleached cherries during harvesting, handling, and processing. Average of 2 harvests. Northwestern Michigan, 1967

Sampling Stations	Percent Blemished Fruits ¹	
	Fresh	Bleached
1. Hand-picked before mechanical harvesting -----	4.9a	34.0a
2. Dropping from mechanical harvester -----	3.8a	48.0 b
3. Field tanks when they arrive at processing plant -----	3.5a	57.6 b
4. Dropping from rotating scales -----	3.5a	68.5 c
5. After processor soak -----	4.2a	67.5 c
6. Dropping into electric-eye sorter -----	4.2a	71.4 c
7. After electric-eye sorter ----	5.3a	85.0 d

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

Bleaching the northwestern Michigan cherries revealed that the hand-picked cherries had 34 percent blemishes (Table 4), due to wind-whip or related factors. Even though scald was not severe with the short soak, the wind-whip blemishes plus the scald resulted in low grade frozen cherries. The major factors lowering the grade, according to the U.S.D.A. inspector, were visible defects and lack of red color.

It appeared from the 1966 and 1967 data that length of soak was the critical factor in maintaining quality of processed cherry products. As shown in Tables 5 and 6, hand-picked and mechanically harvested cherries consistently increased in percent blemishes classified as scald, as the length of soak increased. Scald was evident on both the fresh and bleached fruits (Tables 5 and 6 and Figures 3 and 4). However, the increase was greater for mechanically harvested cherries than for hand-picked fruits (Figures 3, 4 and 5). As in 1966 and 1967, bleaching vividly revealed the hidden blemishes which were present only in the

Table 5.--Percent blemished fresh and bleached fruits, hand-picked and mechanically harvested, as influenced by length of soak.¹ Average of 3 harvests. Southwestern Michigan, 1968

Length of soak	Percent Blemished Fruits ²			
	Fresh		Bleached	
	Hand- picked	Mechanical Harvested	Hand- picked	Mechanical Harvested
Before soak	3.2a	8.6a	7.8a	18.3a
After 4 hour soak	4.1a	18.8 b	8.7a	22.3ab
After 8 hour soak	4.7a	27.1 c	9.1a	26.4 b
After 12 hour soak	7.1ab	33.8 d	9.8a	33.7 c
After 24 hour soak	11.6 b	49.6 e	11.9a	90.4 d

¹Water temperature ranged from 54 to 56 F.

²Numbers in the same column followed by the same letter are not significantly different (5% level).

Table 6.--Percent blemished fresh and bleached fruits, hand-picked and mechanically harvested, as influenced by length of soak.¹ Average of 3 harvests. Northwestern Michigan, 1968

Length of soak	Percent Blemished Fruits ²			
	Fresh		Bleached	
	Hand- picked	Mechanical Harvested	Hand- picked	Mechanical Harvested
Before soak	10.2a	21.6a	20.4a	28.8a
After 4 hour soak	12.6abc	37.1 b	23.7a	36.0a
After 8 hour soak	14.3abc	52.3 c	20.0a	45.6 b
After 12 hour soak	18.0a c	68.9 d	18.9a	75.6 c
After 24 hour soak	25.7 d	84.6 e	26.1a	98.3 d

¹Water temperature ranged from 51 to 53 F.

²Numbers in the same column followed by the same letter are not significantly different (5% level).

mechanically harvested cherries. Date of harvest in 1968 again had no significant effect on fresh or bleached grade and thus, the data for each soak interval were averaged (Tables 5 and 6).

Fruit size.--Fruit size is important to the grower because of yield and important to the processor because of pitting properties and maintenance of shape after processing. Large cherries may result in softening and collapsed fruit in the processed product as a result of bruising during harvesting, handling, and processing. The average size distribution of cherries collected at the various sampling

Figure 3. Percent blemished fresh and bleached cherries, hand-picked and mechanically harvested, as influenced by length of soak for 3 harvests in southwestern Michigan, 1968

- A. Fresh hand-picked fruits
- B. Fresh mechanically harvested fruits
- C. Bleached hand-picked fruits
- D. Bleached mechanically harvested fruits

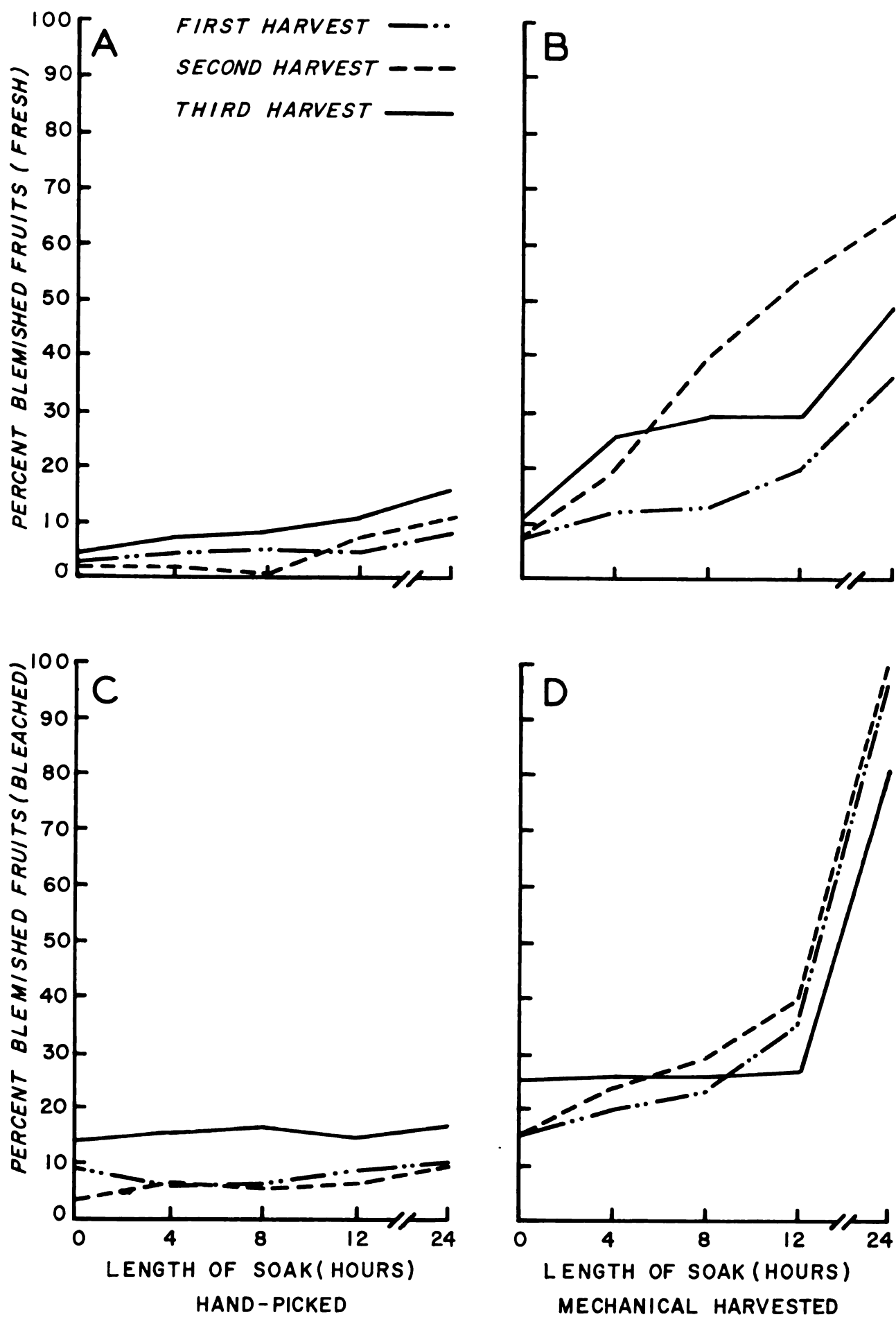


Figure 3

Figure 4. Percent blemished fresh and bleached cherries, hand-picked and mechanically harvested, as influenced by length of soak for 3 harvests in northwestern Michigan, 1968

- A. Fresh hand-picked fruits
- B. Fresh mechanically harvested fruits
- C. Bleached hand-picked fruits
- D. Bleached mechanically harvested fruits

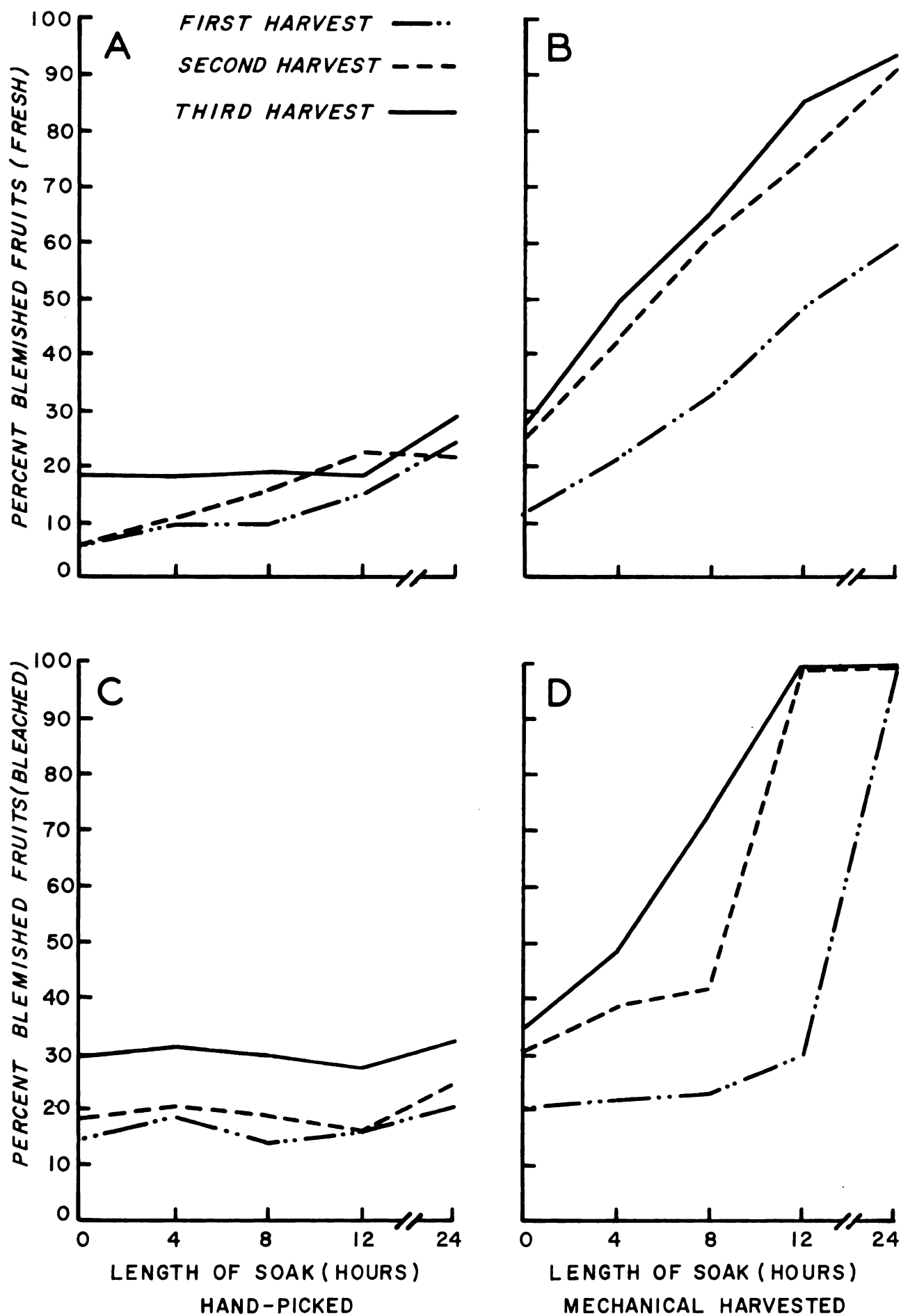


Figure 4

Figure 5. Comparison of scald between hand-picked and mechanically harvested cherries after a 24-hour soak and SO₂-bleaching. Southwestern Michigan, 1968

- A. Hand-picked
- B. Mechanically harvested

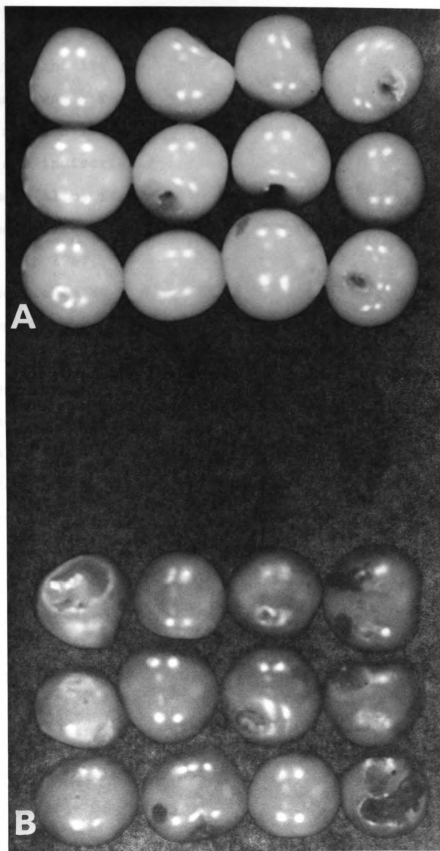


Figure 5

stations in 1966 and 1967 is shown in Tables 7 and 8. Note that in 1966 and 1967, based on number of cherries per 500 grams, there was a reduction in size during mechanical harvesting, station 2. This reduction was probably due to bruising and indiscrimination between fruits by mechanical harvesting. Also, in 1966, the centrifugal pump reduced fruit size (Table 7). This reduction was probably due to bruising. In 1967, the 20 hour processor soak reduced fruit size (Table 8). This reduction implies a loss of water from the cherry during the soak.

In 1968, as in 1966 and 1967, there was a reduction in average fruit size following mechanical harvesting (Tables 9 and 10). The reduction in size of cherries after mechanical harvesting was greater for some harvests than others (Table 10). These variations were not reflected by the firmness data in Figure 6, graphs A and B. These results were typical when comparing firmness of fruit and reduction in size following mechanical harvesting.

Fruit soluble solids.--Refractometer readings of soluble solids in sour cherries reflect primarily sugar content, but other solutes are measured by the reading. There is no established level for soluble solids in processed cherries, but processors are interested in maintaining sufficient sugars in the final product to appeal to the consumer. When soluble solids in the fresh product are

Table 7. Size distribution of cherries during harvesting, handling, and processing.
Average for 3 harvests. Southwestern Michigan, 1966

Sampling Stations	Percent of Total Sample			No. of cherries per 500-grams
	<4/8"	4/8"-5/8"	5/8"-6/8"	>6/8"
1. Hand-picked before mechanical harvesting -----	0	2	41	57
2. Dropping from mechanical harvester -----	6	4	42	48
3. Field tanks when they arrive at processing plant -----	6	6	41	47
4. Dropping from rotating scales (Centrifugal pump)	3	10	40	47
5. Holding tank inside plant ---	12	2	43	43
6. Dropping into electric-eye sorter -----	11	4	41	44
7. After electric-eye sorter ---	13	6	40	41

Table 8. Size distribution of cherries during harvesting, handling, and processing.
Average for 3 harvests. Southwestern Michigan, 1967

Sampling Stations	Percent of Total Sample			No. of Cherries per 500-grams
	<4/8"	4/8"-5/8"	5/8"-6/8"	>6/8"
1. Hand-picked before mechanical harvesting -----	0	1	89	10
2. Dropping from mechanical harvester -----	2	11	84	3
3. Field tanks when they arrive at processing plant -----	1	6	88	5
4. Dropping from rotating scales -----	2	10	86	3
(Processor soak)				
5. Belt before destemmer -----	9	17	74	0
6. Flume after destemmer -----	8	16	75	1
7. Holding tank inside plant -----	3	21	75	1
8. Dropping into electric-eye sorter -----	6	13	79	2
9. After electric-eye sorter -----	9	15	76	0

Table 9.--Size distribution of hand-picked and mechanically harvested cherries from 3 harvests. Southwestern Michigan, 1968

Harvest		Percent of Total Sample				No. of Cherries per 500- grams
No.	Date	<4/8"	4/8"-5/8"	5/8"-6/8"	>6/8"	
First	7/8					
Hand-picked		0	11	78	11	103
Mechanical		0	14	79	8	106
Second	7/15					
Hand-picked		0	19	78	3	111
Mechanical		1	32	64	3	114
Third	7/20					
Hand-picked		0	1	41	58	86
Mechanical		1	7	64	28	88

Table 10.--Size distribution of hand-picked and mechanically harvested cherries from 3 harvests. Northwestern Michigan, 1968

Harvest		Percent of Total Sample				No. of Cherries per 500- grams
No.	Date	<4/8"	4/8"-5/8"	5/8"-6/8"	>6/8"	
First	7/31					
Hand-picked		0	6	82	12	90
Mechanical		1	12	85	2	98
Second	8/1					
Hand-picked		0	5	90	5	99
Mechanical		2	26	70	2	108
Third	8/2					
Hand-picked		0	11	86	3	110
Mechanical		2	31	67	0	113

low, the processor must add more sugar than when soluble solids are high.

The percent soluble solids at the various sampling stations during harvesting, handling, and processing in 1966 and 1967 are shown in Tables 11 and 12.

There was a slight increase in soluble solids after mechanical harvesting as compared to hand-picked cherries (Tables 11 and 12). This increase may have been due to a loss of water during mechanical harvesting or a physiological and/or chemical conversion of insoluble solids to

Table 11.--Percent soluble solids during harvesting, handling, and processing. Average of 3 harvests. Southwestern Michigan, 1966

Sampling Station	Percent Soluble Solids ¹
1. Hand-picked before mechanical harvesting	12.7a
2. Dropping from mechanical harvester -----	13.1a
3. Field tanks when they arrive at processing plant -----	12.6a
4. Dropping from rotating scales ----- (Centrifugal pump)	12.5a
5. Holding tank (boot) inside plant -----	12.4a
6. Dropping into electric-eye sorter -----	12.7a
7. After electric-eye sorter -----	12.6a

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

Table 12.--Percent soluble solids of cherries during harvesting, handling, and processing. Average of 3 harvests. Southwestern Michigan, 1967

Sampling Station	Percent Soluble Solids ¹
1. Hand-picked before mechanical harvesting -----	13.9a
2. Dropping from mechanical harvester ----	14.5 b
3. Field tanks when they arrive at processing plant -----	13.4a
4. Dropping from rotating scales ----- (Processor soak)	13.4a
5. Belt before destemmer -----	12.7 c
6. Flume after destemmer -----	12.7 c
7. Holding tank inside plant -----	12.6 c
8. Dropping into electric-eye sorter ----	12.6 c
9. After electric-eye sorter -----	12.9 c

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

soluble solids as the result of bruising. However, this increase was lost after the cherries were soaked a short time in water, sample station 3 in Tables 11 and 12.

The findings of 1967 revealed a loss of a little less than 1 percent soluble solids following the processor soak, station 5 in Table 12. A 2 percent reduction in soluble solids of sour cherries during a 12-to 24-hour soak when the cherries were bruised has been reported (29, 66).

Fruit firmness.--Flesh firmness of sour cherries was determined for the samples collected at the various sampling stations in 1967 (Table 13, Figure 6). Firmness of the cherries during harvesting, handling, and processing did not change significantly between harvests thus, the averages are shown. However, firmness for the fruits of the individual harvests were plotted to show more vividly the gradual loss in flesh

Table 13.--Firmness of cherry flesh during harvesting, handling, and processing. Average of 3 harvests. Southwestern Michigan, 1967

Sampling Stations	Firmness (grams) ¹
1. Hand-picked before mechanical harvesting ----	40.9a
2. Dropping from mechanical harvester -----	34.1 b
3. Field tanks when they arrive at processing plant-----	37.6 c
4. Dropping from rotating scales ----- (Processor soak)	37.2 c
5. Belt before destemmer -----	36.8 c
6. Flume after destemmer -----	36.2 c
7. Holding tank inside plant -----	30.8 d
8. Dropping into electric-eye sorter -----	30.9 d
9. After electric-eye sorter -----	28.6 d

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

Figure 6. Firmness of cherry flesh during harvesting, handling, and processing, 1967

A. Southwestern Michigan, 3 harvests

Sampling stations

1. Hand-picked before mechanical harvesting
2. Dropping from mechanical harvester
3. Field tanks when they arrive at processing plant
4. Dropping from rotating scales
(Processor soak)
5. Belt before destemmer
6. Flume after destemmer
7. Holding tank inside plant
8. Dropping into electric-eye sorter
9. After electric-eye sorter

B. Northwestern Michigan, 2 harvests

Sampling stations

1. Hand-picked before mechanical harvesting
2. Dropping from mechanical harvester
3. Field tanks when they arrive at processing plant
4. Dropping from rotating scales
(Processor soak)
5. Flume after soaking
6. Dropping into electric-eye sorter
7. After electric-eye sorter

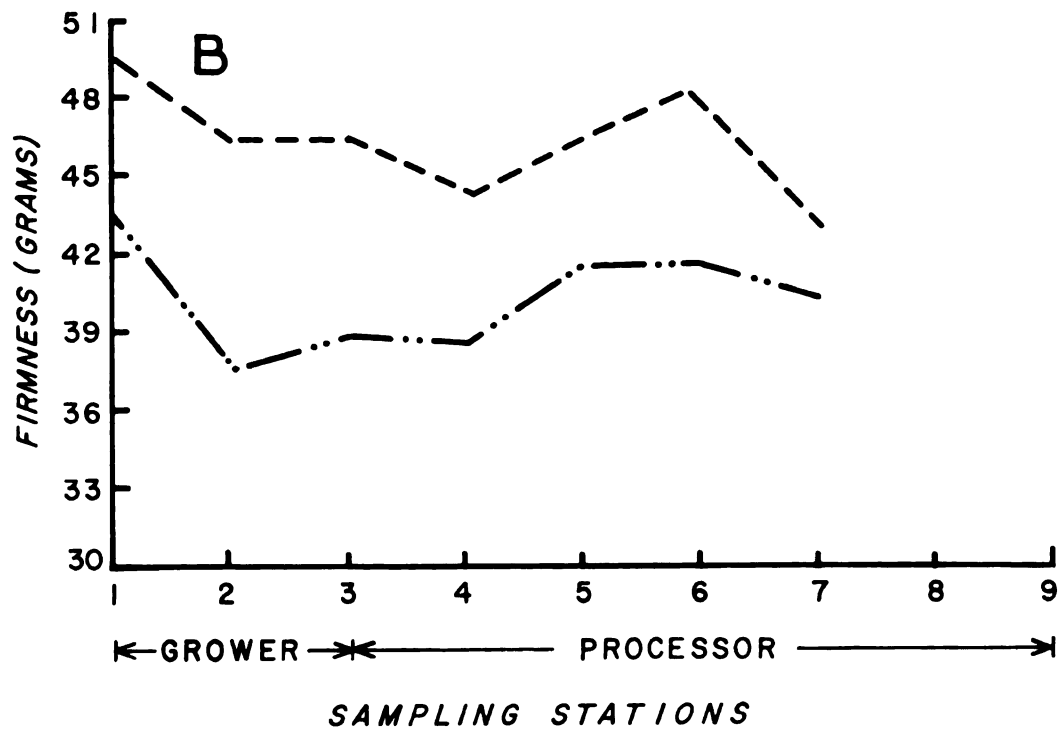
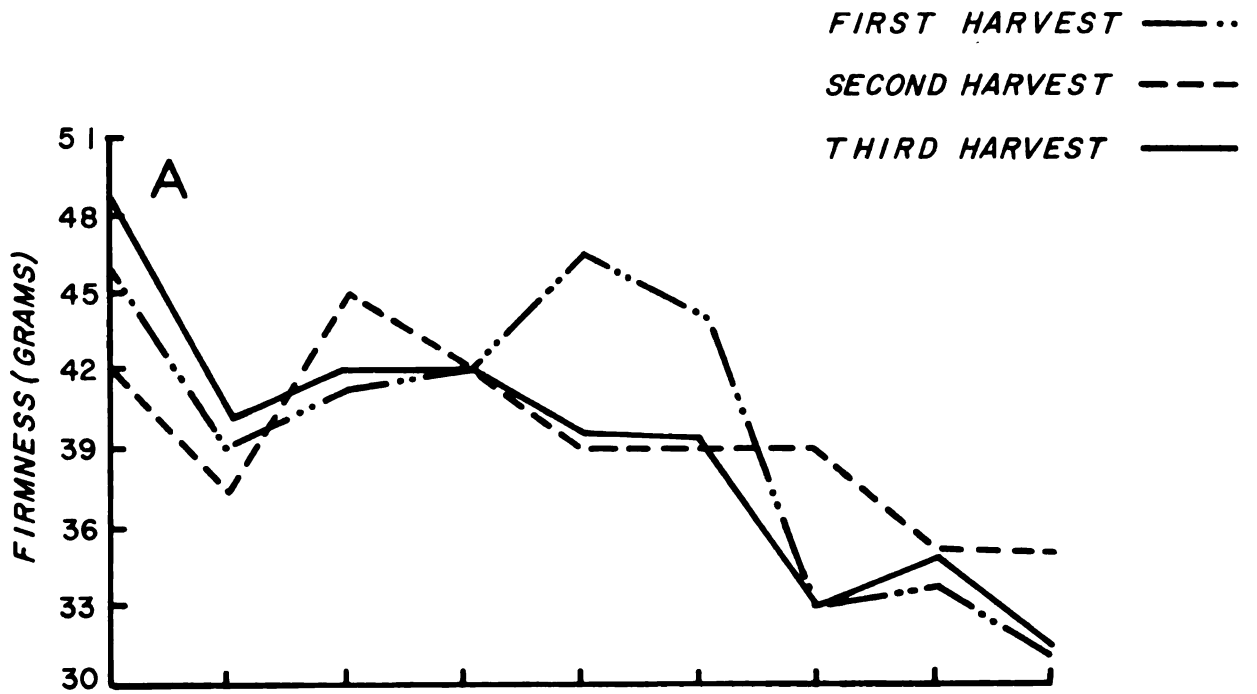


Figure 6

firmness during processing (Figure 6). There was a significant loss in firmness from mechanical harvesting (Table 13 and Figure 6), a recovery while soaking in the grower's field tank (station 3), and a second loss again during processing (station 7).

Soak trials in 1968 revealed that length of soak had little effect on the firmness of hand-picked cherries. However, there was a significant increase in firmness of mechanically harvested cherries after the 24-hour soak. Nevertheless, in every case, the mechanically harvested cherries were softer than the hand-picked cherries throughout the soak period (Tables 14 and 15). The changes in firmness of flesh with length of soak are presented graphically for the individual harvests in Figures 7 and 8.

Table 14.--Firmness of hand-picked and mechanically harvested cherries with length of soak. Average of 3 harvests. Southwestern Michigan, 1968

Length of soak	Firmness (grams) ¹	
	Hand-picked	Mechanical Harvested
Before soak	54.6a	45.7a
After 4 hour soak	54.7a	47.1 b
After 8 hour soak	55.0a	47.2 b
After 12 hour soak	55.2a	47.3 b
After 24 hour soak	55.3a	48.4 c

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

Table 15.--Firmness of hand-picked and mechanically harvested cherries with length of soak. Average of 3 harvests. Northwestern Michigan, 1968

Length of soak	Firmness (grams) ¹	
	Hand-picked	Mechanical Harvested
Before soak	53.7 b	46.6a
After 4 hour soak	51.1a	46.4a
After 8 hour soak	51.7a	47.1a
After 12 hour soak	51.7a	47.3a
After 24 hour soak	53.7 b	49.3 b

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

Fruit color.--Color is a very important factor in fresh cherry quality. Peel color is a factor considered commercially by the U.S.D.A. fresh fruit inspector in determining the grade of cherries delivered to the processing plant. Fresh cherries are bought and sold upon the basis of this grade.

Fruit color is also a criteria in determining the grade of the processed product. Color was evaluated in cherries from the various sampling stations in 1967 to determine changes during the procedures of harvesting, handling or processing. There was a loss of red color from the peel as the cherries passed through the handling and processing procedures, with the greatest loss occurring during the processor soak (Table 16).

Figure 7. Firmness of the flesh of hand-picked and mechanically harvested cherries as influenced by length of soak. Southwestern Michigan, 1968

- A. First harvest - July 8
- B. Second harvest - July 15
- C. Third harvest - July 20

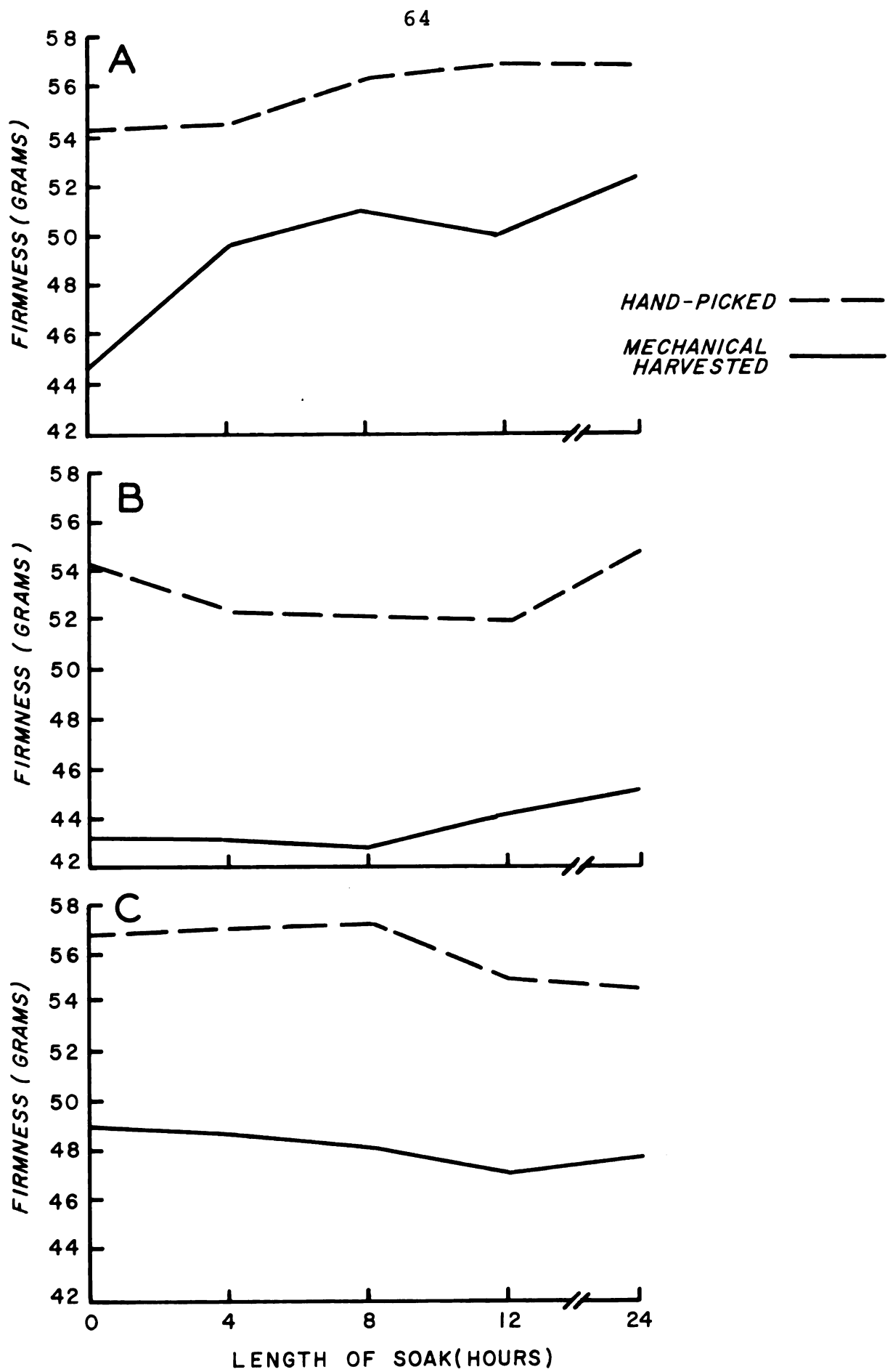


Figure 7

Figure 8. Firmness of the flesh of hand-picked and mechanically harvested cherries as influenced by length of soak. Northwestern Michigan, 1968

- A. First harvest - July 31
- B. Second harvest - August 1
- C. Third harvest - August 2

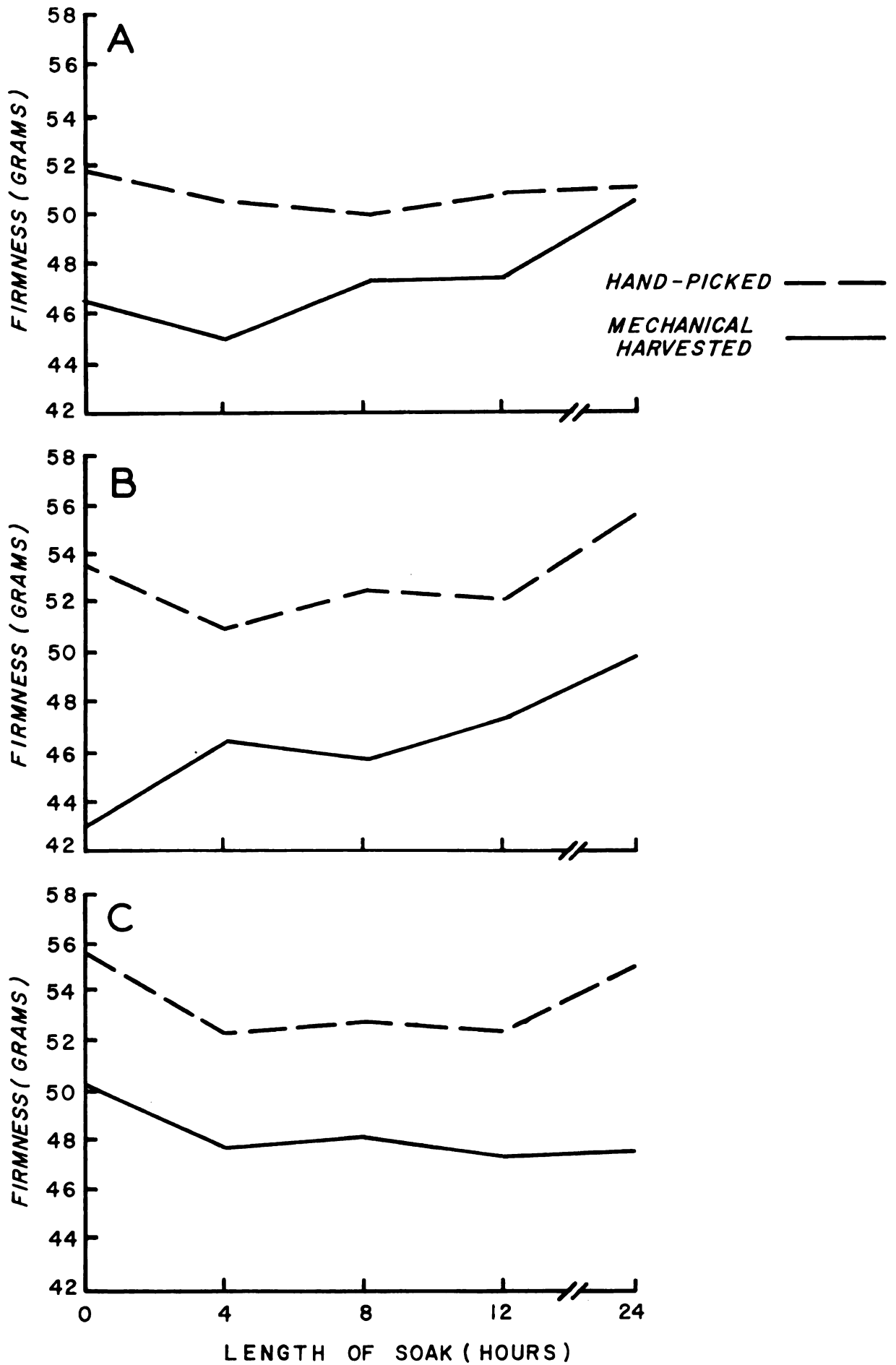


Figure 8

Table 16.--Peel color of cherries during harvesting, handling, and processing as measured by light transmission.¹ Average of 3 harvests. Southwestern Michigan, 1967

Sampling Stations	Percent Light Transmission (515mu) ²
1. Hand-picked before mechanical harvesting -----	19.5a
2. Dropping from mechanical harvester	12.9a
3. Field tanks when they arrive at processing plant -----	14.1a
4. Dropping from rotating scales ---- (Processor soak)	15.4a
5. Belt before destemmer -----	39.6 b
6. Flume after destemmer -----	38.2 b
7. Holding tank inside plant -----	50.3 c
8. Dropping into electric-eye sorter	39.8 b
9. After electric-eye sorter -----	45.0 bc

¹The higher the value the smaller the amount of red pigment.

²Numbers in the same column followed by the same letter are not significantly different (5% level).

Because of the loss of red color in 1967, color was again evaluated in 1968 for hand-picked and mechanically harvested cherries, with varying lengths of soak. The studies in both southwestern and northwestern Michigan revealed a significant loss of red color from the peel of mechanically harvested cherries after the 24-hour soak

(Tables 17 and 18). However, this loss was not evident for hand-picked cherries indicating an interaction of bruising and length of soak with change in peel color.

Table 17.--Peel color of hand-picked and mechanically harvested fruits as influenced by length of soak and measured by light transmission.¹ Average of 3 harvests. Southwestern Michigan, 1968

Length of Soak	Percent Light Transmission (515mu) ²	
	Hand-picked	Mechanical Harvested
Before soak	15.5a	14.8a
After 4 hour soak	15.7a	13.8a
After 8 hour soak	15.8a	15.4a
After 12 hour soak	16.6a	17.3ab
After 24 hour soak	15.4a	19.5 b

¹The higher the value the smaller the amount of red pigment.

²Numbers in the same column followed by the same letter are not significantly different (5% level).

Fruit respiration.--Respiration rate has been reported by Ulrich (58) to reflect the stage of fruit maturity. Pollack (49) indicated that bruising, and the subsequent disruption of the normal respiratory system of the fruit, was a primary factor in the formation of surface scald. Due to the large amount of scald found in mechanically harvested cherries in 1966 (Table 1), respiratory activity of hand-picked and mechanically harvested cherries

Table 18.--Peel color of hand-picked and mechanically harvested fruits as influenced by length of soak and measured by light transmission.¹ Average of 3 harvests. Northwestern Michigan, 1968

Length of Soak	Percent Light Transmission (515m) ²	
	Hand-picked	Mechanical Harvested
Before soak	22.8a	26.2a
After 4 hour soak	21.5a	27.5a
After 8 hour soak	23.0a	27.0a
After 12 hour soak	20.4a	30.6a
After 24 hour soak	22.2a	40.2 b

¹The higher the value the smaller the amount of red pigment.

²Numbers in the same column followed by the same letter are not significantly different (5% level).

was measured using cherries from 2 blocks of trees in Southwestern Michigan in 1967. Cherries were hand-picked from the same trees approximately 2 weeks and one week before harvest to evaluate the change in respiration as the fruits approached maturity. Rate of respiration of mechanically harvested and hand-picked cherries was compared.

There was no significant change in CO₂-evolution of hand-picked cherries between harvests, Table 19. However, there was a significant increase in respiratory activity of mechanically harvested cherries when compared to hand-picked cherries (Table 19). Thus, these data reflect a

Table 19.--Respiration (CO₂-evolution) of cherries as influenced by date of harvest and mechanical harvesting. Southwestern Michigan, 1967

Harvests		Ml. CO ₂ /Kg./24 hr. (20°C) ¹	
No.	Date	Block 1	Block 2
First (hand)	7/5	391.7a	371.3a
Second (hand)	7/16	403.8a	380.4a
Third (hand)	7/20	408.8a	381.1a
(mech)	7/20 ²	499.9 b	-----
Fourth (hand)	7/24	-----	385.5a
(mech)	7/24 ³	-----	591.7 b

¹Numbers in the same column followed by the same letter are not significantly different (5% level).

²Commercial harvest for block 1.

³Commercial harvest for block 2.

disruption of the normal respiratory system by mechanical harvesting as reported by Pollack (49).

Histological evaluation.--An anatomical evaluation of fresh cherries indicated that, based on the presence of exude deposited during healing, much of the injury occurred on the tree. However, certain types of injury resulted from mechanical harvesting, handling, and processing.

The wind-whip scar in Figure 9a occurred on the tree. When cut in cross-section (Figure 9b) it appeared that the split extending into the cortical tissue was filled with an exudate, healing the injury.

Figure 9. External and internal injury of cherry fruits on the tree and during mechanical harvesting, handling, and processing. Southwestern Michigan, 1967

- a. Wind-whip scar occurring on the tree (SO₂ bleached cherry)
- b. Cross-section of wind-whip scar shown in Figure 9 a. Phase contrast, 125X
- c. Shearing of cortical cells. Cherry collected after mechanical harvesting, Phase contrast, 125X
- d. Internal injury. Cherry hand-picked from tree. Phase contrast, 125X
- e. Sub-epidermal injury. Cherry hand-picked from tree. Phase contrast, 125X
- f. Tissue of non-scalded cherry hand-picked from the tree. Phase contrast, 125X
- g. Tissue of scalded cherry collected after processor soak. Phase contrast, 125X

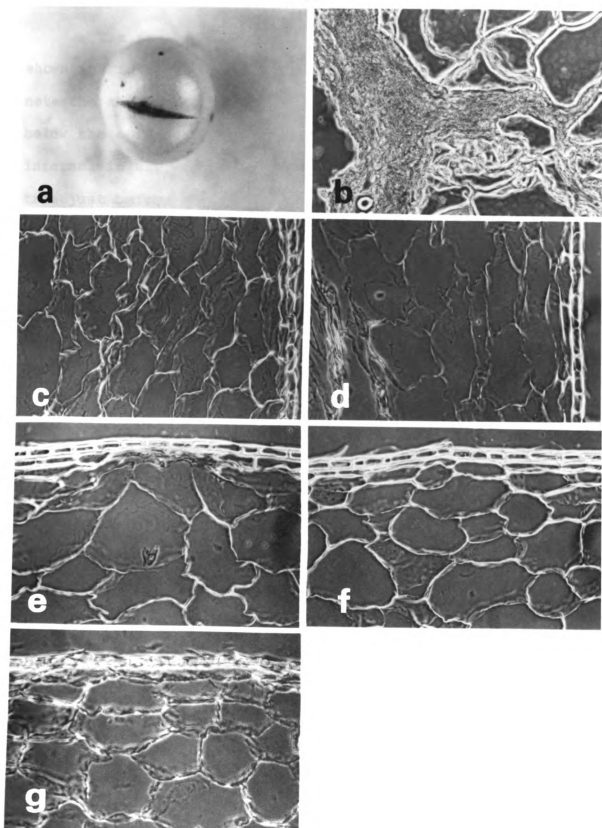


Figure 9



The section of mechanically harvested cherry tissue shown in Figure 9c appeared unbruised in surface view, but note the shearing of cortical cells approximately 4 cells below the epidermis. However, a similar shearing type of internal injury was found in cherries hand-picked from the tree just before mechanical harvest, Figure 9d.

The section of hand-picked cherry tissue in Figure 9e revealed that the epidermis was neatly intact with crushed cells beneath. In surface view this injury appeared as a dark brown area.

From microscopic examination all the darkened bruises of mechanically harvested cherries appeared to have occurred on the tree.

Scald appeared to be the principal defect of mechanically harvested cherries and there appeared to be a direct correlation between bruising and scalding. Therefore, scalded and non-scalded tissue was sectioned and observed microscopically to detect any anatomical differences.

The tissue of scalded and non-scalded cherries showed no crushing or distortion of cells. However, the epidermis of the scalded tissue appeared dense (Figure 9g), and the cell walls appeared thicker than those of the non-scalded tissue (Figure 9f). The cells within the epidermal tissue were free of distortion and apparent injury. Apparently, these cells had developed sufficient resilience during ripening to withstand impact during harvest.

Since the cells of scalded tissue did not appear to be distorted, bruising apparently induced a physiological change or membrane disruption which resulted in discoloration, or, as Pollack reported (49), the scalding may have resulted from disruption of the normal respiratory system as has been shown in this study (Table 19).

Oxidized tannins are reported to be primarily responsible for the brown color associated with scald (35, 38, 71). In view of these reports, in 1968, hand-picked and mechanically harvested cherries collected before soaking and after the 4, 8, 12, and 24-hour soak were stained with ferrous sulfate (30) in the hope of revealing possible tannins in injured epidermal cells.

According to Esau (17), tannins are commonly localized in the epidermal region of fruits. Sections of the cherries soaked in ferrous sulfate revealed the presence of tannins (Figure 10a and 10c). However, during the 24-hour soak, there was a slight movement of tannins into the cortex (Figures 10b and 10d), but the movement appeared to be greater for mechanically harvested (Figure 10d), than for hand-picked cherries (Figure 10b). The cellular disruption resulting from bruising during mechanical harvesting, (Figure 10c) apparently were discolored due to their high tannin content which carried over into the processed product. Of interest, the Federal Fruit Inspection Service



Figure 10. Cross-sections of hand-picked and mechanically harvested cherries before soaking and after soaking for 24-hours, stained with ferrous sulfate to show tannin content. Bright field 50X

- a. Hand-picked cherry before soaking
- b. Hand-picked cherry after 24-hour soak
- c. Mechanically harvested cherry before soaking
- d. Mechanically harvested cherry after 24-hour soak

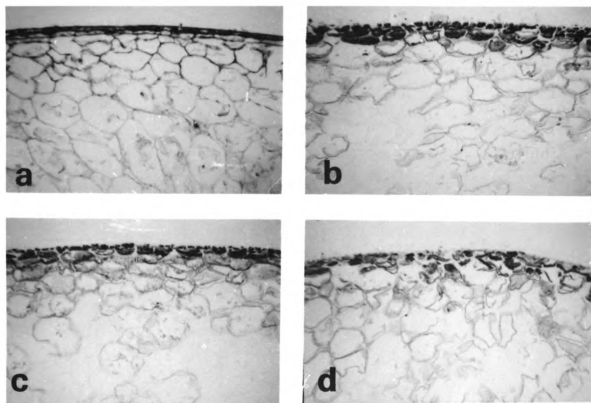


Figure 10

of the U.S.D.A. reported unofficially that the principal defect of processed Michigan cherries in 1968 was scald or loss in red color.

SUMMARY

Studies were conducted in 1966, 1967, and 1968 to (a) determine the factors responsible for loss in quality of fresh and processed sour cherry fruits, (b) determine what phase(s) of the harvesting, handling, and processing procedure results in the major loss in quality, and (c) compare fruits harvested and handled in different ways to determine possible tissue, cell and chemical differences which could account for loss in quality.

In 1966 and 1967, cherries were collected at various stations within the harvesting, handling, and processing procedure and evaluated for changes in fruit quality. As a result of the 1966 and 1967 findings, in 1968, hand-picked and mechanically harvested cherries were soaked for 4, 8, 12, and 24-hours to evaluate changes in fruit quality as influenced by length of soak.

The results showed that, as regards:

Blemished Fruits

1. SO₂-bleaching revealed bruises masked by red pigment.
2. Based on percent blemished fresh fruit, the fresh grade did not accurately reflect the grade of the processed product. Whereas, the bleached grade did.

3. After bleaching there was a gradual increase in percent blemished fruits during mechanical harvesting, handling, and processing with the major increase due to scalding during the processor soak.
4. There was a significant increase in scald when mechanically harvested cherries were soaked for 8 hours and longer. However, the scald was not evident until the cherries were bleached. Increase in scald was not significant for the bleached hand-picked cherries even after a 24-hour soak.

Fruit Size

1. There was a reduction in fruit size after mechanical harvesting.
2. There was a reduction in fruit size after the processor soak.

Fruit Soluble Solids

1. There was a significant increase in percent soluble solids after mechanical harvesting. However, this increase was lost during the soak in the field tanks.
2. There was a second slight but significant drop in percent soluble solids after the processor soak.

Fruit Firmness

1. Mechanical harvesting significantly reduced flesh firmness, but there was a significant recovery

after soaking in the growers field tank, followed by a second loss during processing operations.

2. There was a significant increase in firmness of mechanically harvested cherries after a 24-hour soak, but length of soak had no significant effect on firmness of hand-picked cherries. During soak the mechanically harvested cherries were softer than hand-picked cherries.

Fruit Color

1. Red color was lost from the peel as mechanically harvested cherries moved through the handling and processing procedures, with the greatest loss occurring during a 24-hour soak by the processor.
2. However, when comparing mechanically harvested and hand-picked cherries, after a 24-hour soak there was a significant loss of red color from the peel of only the mechanically harvested cherries, indicating an interaction of bruising and length of soak with change in peel color.

Fruit Respiration

1. Respiratory activity was significantly greater for mechanically harvested cherries than for hand-picked cherries.
2. This increased respiratory activity of mechanically harvested cherries appeared to be related to scald formation.

Histological Evaluation

1. Microscopic examination indicated that darkened bruises on the epidermis of the cherries occurred prior to mechanical harvesting.
2. Sections of tissue of scalded cherries showed no crushing or distortion of cells, but the epidermal cells appeared dense, and the cell walls appeared to be thicker than those of non-scalded tissue.
3. Since the cells of scalded tissue did not appear to be distorted, bruising apparently induced a physiological change or membrane disruption which resulted in discoloration.
4. Tannins were located primarily in the epidermal region, but during a 24-hour soak there was a slight movement of tannins into the outer cortical cells with the movement being greater in mechanically harvested cherries than in hand-picked. The cellular disruption resulting from bruising by mechanical harvesting possibly aided the movement of tannins inward from the epidermal area.

In this 3-year study, the single defect resulting from mechanical harvesting which reduced the grade of processed sour cherries was scald. Also, the findings revealed that the scald was not a factor until the mechanically harvested cherries were soaked longer than 8 hours before processing.

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