SENSORY AND OBJECTIVE COMPARISON OF FROZEN, IQF, DRIED, AND CANNED MONTMORENCY CHERRIES IN PIES

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ABSTRACT

SENSORY AND OBJECTIVE COMPARISON OF
FROZEN, IQF, DRIED, AND CANNED
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by Onolee DeGroff Franks

This investigation was initiated to determine the effect of canning, freezing, individual quick freezing and drying on the color, viscosity, and palatability of cherry pie fillings. The study, also, included determination of the following: the effect of use of commercial red food coloring on acceptability of dried cherries in pies; the effect of sodium bisulfite treatments on the color and quality of dried cherries; and the effect of freezing on the quality of dried cherries in pies. Subjective and objective measurements were utilized to evaluate the cherry pie fillings. Six replications of each of the variables were tested and collected data were statistically analyzed by a computer.

Sensory evaluation of cherry pie fillings indicated that the color and appearance of frozen and IQF cherry pie fillings received significantly higher scores than those of canned and dehydrated cherry

pie fillings; the tenderness of cherry skin of frozen, IQF, and dehydrated cherries were not significantly different; the nonsodium bisulfite-treated- and sodium bisulfite-treated-dried cherries scored significantly lower for color, flavor, and acceptability than the other cherry variables.

The Hunter color-difference meter was utilized to determine the lightness, redness, and yellowness values of cherry pie fillings. However, only the redness values significantly correlated with those obtained by the sensory panel for cherry color. The redness values of IQF cherry fillings were significantly higher and the sodium bisulfite-treated- and nonsodium bisulfite-treated-dried cherry fillings were significantly lower than the other cherry variables.

The Kramer shear press used to determine cherry tenderness indicated that greater force was needed to shear IQF cherries than all other types of processed cherries. There were no significant differences among the force readings of frozen and dried cherry variables. Also, there was no significant correlation between shear press measurements and sensory evaluation of tenderness of cherry skin.

Frozen pies prepared with dried cherries were subjected to sensory and objective measurements and the results were compared with those pie fillings freshly prepared with dried cherries. Although no significant differences were found between the two products, both products received low acceptability scores.

Although this investigation has indicated that frozen, IQF, canned, and dried-with-coloring-added Montmorency cherries produced acceptable pies, additional research is needed in the following areas: (1) an investigation to determine the effect of pretreatment with higher concentrations of sodium bisulfite on color retention in dehydrated cherries; (2) an investigation to determine use and acceptability of dried cherries in other baked products; and (3) a study to determine the effect of storage time on color and palatability of frozen, IQF, canned and dehydrated cherries.

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By

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INTRODUCTION

Michigan is the leading state in the production of red tart (sour) cherries. Montmorency variety is processed because of the excellent quality, the firmness in flesh, the size of the fruit, the long harvest season, and because it is a dependable producer of a good crop (Marshall, 1954).

The average annual tart cherry production in the United States during 1958-66 was 137,000 tons. In a normal year, when the cherry industry does not sustain losses from the late spring frost or other adverse weather conditions, production has reached 224,044 tons (Table 1). However, the processor capacity and storage space are sufficient to handle only about 110,000 tons (Larsen et al., 1966). Therefore new processing techniques for handling surplus cherries in normal years are needed in order to reduce profit loss and provide additional cherries for low production periods.

Presently canning and freezing are the only methods of preservation being used extensively on a commercial basis; however, newer processes, dehydration and individual quick freezing, are in the experimental stage. Both of these techniques offer the economical advantage of reduced weight in transport, through removal of water in the dehydration process and elimination of sugar in the individual quick freezing process. The dehydration technique also offers the advantage of economical packaging, storage at room temperature, and handling surplus cherries in normal years. Of these two, the individual quick freezing process is less economical due to the higher cost of frozen storage, the utilization of more space, and insufficient freezer capacity and storage space to handle surplus cherries.

Table 1. Production and utilization of sour cherries in United States.

Year	Fresh tons	Canned tons	Frozen tons	Brined tons	Total Sales tons
1958	6,398	47,739	46,588	765	101,490
1959	5,826	71,225	58,320	1,000	136,371
1960	5,087	44,332	64,168	1,100	114,687
1961	6,840	62,723	93,870	400	163,833
1962	6,036	84,293	73,676	1,670	165,675
1963	4,092	30,860	44,350	700	80,002
1964	7,679	99,641	115,884	840	224,044
1965	4,903	68,193	85,001	1,725	159,822
1966	4,747	37,988	46,166	4	88,901

Source: The Almanac of the Canning, Freezing, Preservation Industries. 1967.

At the present time the sale potential of tart cherries is about 1.3 pounds per capita (Larsen et al., 1966). It is felt that this will remain rather stable unless the cherry industry (1) learns to alleviate or live with the wide production fluctuation or related factors, and (2) develops new products or new utilization methods for cherries.

However, before the cherry processors will produce new or modified cherry products, the quality and acceptability of the product must be determined. Therefore, this investigation was initiated to compare sensory and objective quality characteristics of two new types, dried and individual quick frozen (IQF), with the two standard and accepted methods of processing, frozen and canned. Since red tart cherry pie is the most popular dish prepared from this fruit, it was used as the testing medium.

The primary purpose of this investigation was then to determine the effect of canning, freezing, individual quick freezing (IQF) and drying of cherries on the color, texture, and palatability of pie fillings. Secondary objectives included comparison of quality characteristics of frozen and nonfrozen pies, both prepared with dried cherries; to determine the effect of the addition of commercial red food coloring on the acceptability of dried cherries in pies; and to determine the effect of sodium bisulfite treatments on the color and quality of dried cherries.

REVIEW OF LITERATURE

Composition of Cherries

Only a few research groups have studied the chemical composition of cherries (Marshall, 1954). All of these analyses, based on chemical composition of the pit-free portions of the fruit, vary due to difference among studies in one or more of several factors: variety, degree of maturity at time of harvesting, environmental factors and methods employed in analyses (Marshall, 1954).

Water

Canning and freezing processes alter the original moisture content of cherries (Table 2). Drained canned cherries have a higher moisture content than fresh cherries due to the migration of water medium into the cherry flesh. However, there is a decrease in the moisture content of frozen cherries preserved with dry sugar, due to osmosis. In this process there is diffusion of water molecules from a region of low sugar concentration (fruit) to a region of high concentration (dry sugar) until a state of dynamic equilibrium is established.

Table 2. Composition of fresh, canned, and frozen sour cherries.[a]

Constituents	Fresh	Canned (water-packed)	Frozen (sugar-packed)
Water (%)	83.7	88.0	70.6
Protein (g)	1.2	.8	1.0
Fat (g)	.3	.2	.4
Carbohydrates (g)	14.3	10.8	28.0
Ash (g)	.5	.3	.2
Vitamin A (IU)	1000	680	480
Thiamine (mg)	.05	.03	.03
Riboflavin (mg)	.06	.02	.06
Niacin (mg)	.4	.2	.3
Ascorbic Acid (mg)	10	5	6

[a]Based on constituents in 100 grams of cherries.

Source: Watt and Merrill. 1963.

Organic Acids

There is a progressive increase in active acidity from the time the youngest fruits were obtainable until the cherries had reached full size (Marshall, 1954). The acidity of red tart cherries has generally been reported either as total titratable acidity or as malic acid (Das, 1964). Acids such as citric, tartaric, and succinic were reported to occur only in traces (Marshall, 1954). In 1964, Das reported the presence of 20 non-volatile organic acids and one volatile inorganic acid in red tart cherries. The following acids were identified: glutamic, aspartic, lactic, shikimic, quinic, galaturonic, glyceric, glycolic, tartaric, malonic, citric, neochlorogenic, isochlorogenic, fumaric, chlorogenic, and phosphoric. The dominate acid isolated in this study was malic acid (1259 mg/100 g fruit).

Carbohydrates

Approximately 50-60 per cent of the total dry matter of the edible portion of red sour cherries is composed of carbohydrates (Constantinides *et al.*, 1964). Ninety-nine per cent or more of this total contain fructose and glucose sugars (Constantinides *et al.*, 1964). Five reducing oligosaccharides, which were not identified, were reported to be present in minute quantities (Constantinides *et al.*, 1964).

Ash

The ash of cherries includes minute quantities of many mineral salts including: calcium, phosphorous, iron, sodium, and potassium, with potassium being the highest mineral constituent present (Marshall, 1954). Cherries rank intermediate among the commonly grown fruits in respect to total ash constituent.

Vitamins

Sour cherries contain vitamin A, thiamine, riboflavin, niacin, and ascorbic acid (Table 2). In comparison to other fruits, the cherry is one of the best sources of riboflavin. Ascorbic acid is higher in cherries than in other deciduous tree fruits, but is only 12-25 per cent of that found in citrus fruits (Marshall, 1954).

Color of Cherries

Many fresh fruits owe a considerable part of their attractiveness and consequent popularity to the bright red and purple colors of the anthocyanin pigments (Culpepper *et al.*, 1927). In 1956, two anthocyanin pigments of red tart cherries, antirrhinin and mecocyanin, were isolated and identified by Li *et al.*, 1956.

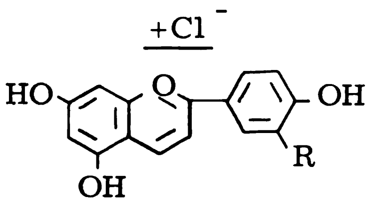
Anthocyanin Pigments

The anthocyanin pigment occurs in plant cells as glucosides which are ethers of monosaccharides, sometime with one monosaccharide moeity and sometime two (Meyer, 1960). When the glucoside is hydrolyzed with acid, alkali, or enzyme, the sugar and sugar-free residue is obtained (Lowe, 1955). This residue is known as anthocyanidin and alteration of its structure changes the color of the anthocyanin.

anthocyanin ⟶ anthocyanidin + monosaccharide

Glidden (1953) reported only three general types of anthocyanidin have been isolated:

I



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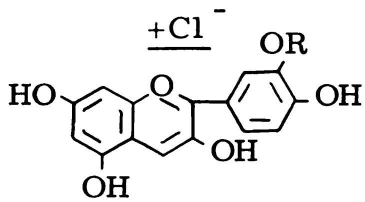
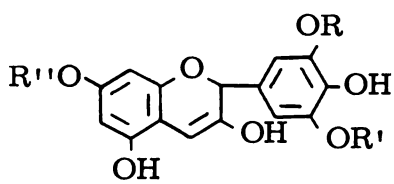
II



cyanidin chloride

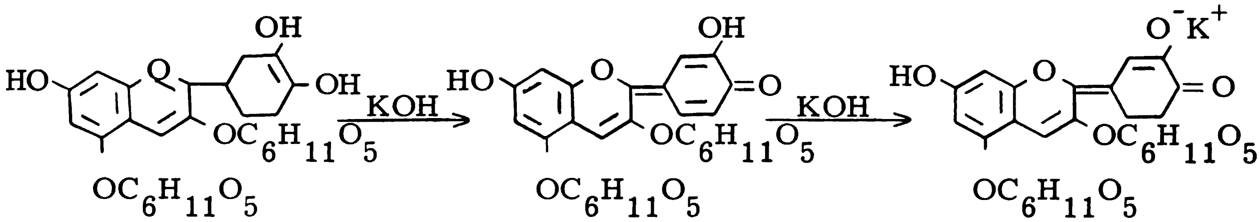
III



delphinidin chloride

The numerous variations of anthocyanin pigment have been found to be methyl ethers of these three general types (Robinson, 1933a; Robinson et al., 1932b).

The anthocyanins and the anthocyanidins are amphoteric in nature and yield salts of both acids and bases. The acid salts are red in color while the basic salts are blue (Glidden, 1953). An example of a basic reaction was reported in Meyer (1960).



Cyanin	color base	salt
red at pH 3.0 or less	violet pH 8.5	blue pH 11.0

Factors Affecting Color in Cherries

In cherries the anthocyanin pigments occur in the cells of the skin, but not in the flesh. Processing the fruit distributes the anthocyanin throughout the tissue (Griswold, 1962). The variation in color of the anthocyanin pigments of cherries is influenced by many factors: care during harvesting, presence of metal cations, enzymes, sugar, ascorbic acid, sulfur dioxide treatments, pH, and storage conditions.

Care during harvesting. Rough handling of cherries during harvesting and transporting to the processing plant bruises the fruit flesh. If the cherries are bruised before soaking, loss of red pigments from the injured tissues becomes apparent within two or three hours. This occurs since the water soluble pigments can diffuse readily and eventually all are leached from the fruit (Van Buren et al., 1959). This study further showed enzymatic action in the presence of air or O_2 contributes to this conversion of pigment to a colorless form. However, the enzyme is relatively inactive in unbruised fruit because the pigments are separated in the fruit cells from the enzymes that can destroy them. Wittenberger et al. (1956) thus concluded bruising of cherries is the primary cause of surface discoloration.

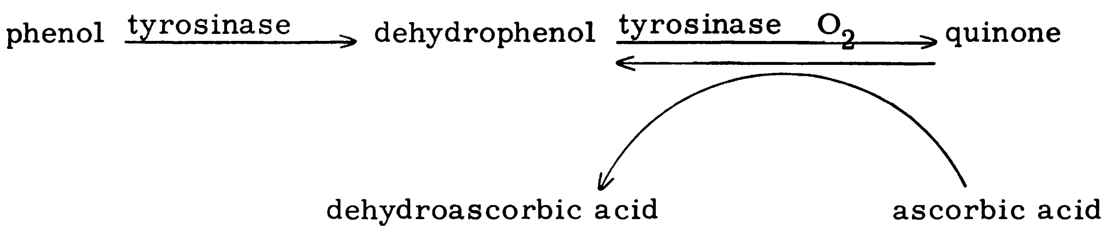
Presence of metallic ions. Culpepper et al. (1927) reported when processing was carried out in glass, the original color was preserved except for lessening in intensity due to partial conversion of the anthocyanin into the colorless form by heat. In tin cans, a greater loss of color occurs, accompanied by the conversion of some pigments to violet and consequent shifting of the color of the product toward purple. This alteration in color resulted from the anthocyanin forming a complex salt with the metal. Griswold (1944), also, reported cherries canned in plain tin were very poor, and those canned in enameled tin compared unfavorably in color and palatability with those canned in glass. Cruess (1948) stated that prolonged heat as well as metallic ions injures the anthocyanin color of canned fruits.

Presence of enzymes. Anthocyanin pigments are phenolic compounds and are readily oxidized or reduced with the loss of red color (Mayak, 1965). Relatively greater enzyme-decolorizing ability was found in those tissues which accumulate the greatest amount of anthocyanin. Thus, the oxidizing activity of the decolorizing enzyme in the skin is greater than that of the less-pigmented flesh (Van Buren et al., 1960). Pung et al. (1963) using mushroom tyrosinase found that in the absence of catechol the reaction was very slow, but in the presence of catechol the rate of mecocyanin discoloration increased rapidly. Thus, they concluded that anthocyanins themselves are poor phenolase substrates; but are readily discolorized by phenolase in the presence of a better substrate, such as catechol, a normal constituent of cherries. Therefore, unless the polyphenoloxidases are inactivated, the catechol will be oxidized to produce O-benzoquinones, which may polymerize to form simple melanins (Mayak, 1965).

The preservation of cherries and other small fruits by a preliminary heat blanching will destroy the enzyme. However, frozen and dried fruits still contain the decolorizing enzyme and continual color loss will occur during storage unless oxygen is excluded or an oxygen inhibitor added.

Presence of sugar. Sugar was found to preserve the brightness of cherry color. Griswold (1944) proposed the theory that sugar either depresses the decomposition of anthocyanin to anthocyanidin plus monosaccharides or protects the pigment from oxidation. Cherries frozen without the addition of sugar or sugar sirup are exposed to air and thus, the anthocyanin pigment will be oxidized and the cherries will darken and discolor.

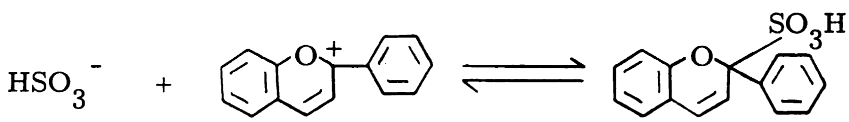
Presence of ascorbic acid. Loutfi (1951), Grommeck *et al.* (1964), and Stein *et al.* (1954) stated that ascorbic acid has protective action on the color of frozen cherries. The presence of oxygen was shown to be detrimental to the color of frozen cherries. Ascorbic acid, an anti-oxidant, maintains the phenolic substrate in the reduced form and thus prevents browning. A schematical presentation of this reaction was given by Mayak (1965).



Loutfi (1951) recommended the use of 175 mg of ascorbic acid per pound package to maintain the fresh flavor and bright color of red sour cherries.

Presence of sulfur dioxide. Sulfur dioxide has been used extensively in the fruit and vegetable industry, chiefly as an inhibitor of microbial growth and of enzymatic and nonenzymatic browning (Goodman *et al.*, 1965). Phenolase oxidase has been shown to catalyze the oxidation of anthocyanin pigments in the presence of the proper phenolic substrate. Sulfur dioxide would be expected to inhibit this degradation of anthocyanin by combining with the enzymatically produced O-quinone, and stopping their condensation to melanins. However, sulfur dioxide is also known to bleach reversibly, the anthocyanin pigments.

The bleaching of anthocyanin by sulfur dioxide is a reversible process that does not involve hydrolysis of the 3-glycoside group, reduction of the pigment, or the addition of bisulfite to a ketone, chalcone derivative (Jurd, 1964). In sulfite discoloration the reactive species is the antho carbonium ion. The experimental evidence indicated that this simply reacts with a bisulfite ion to form a colorless chromen 2(or 4)-sulfonic acid (R-SO_3H), similar in structure and properties to an antho carbinol base (R-OH) (Jurd, 1964).



bisulfite ion　　Antho Carbonium ion　　Chromen sulfonic acid

Stradman (1948) stated sulfur dioxide has proven to be by far the most effective inhibitor tried, and is widely used commercially. Sulfur dioxide treatment is especially beneficial in maintaining normal color of dried fruits; since this type of fruit deteriorates primarily in color and flavor from the browning reaction. However, if fruit does not receive sufficient amount of treatment, quinone formation during storage, in excess of those bound with SO_2, will result in increasing discoloration rates (Embs et al., 1965).

pH. In a study by Grommeck et al. (1964) the results indicated the anthocyanins tested are degraded faster by peroxidases at pH 4.5-5.5 than at other pH levels. They stated the structure of anthocyanin is known to change with pH and this perhaps explains the effect of pH on their oxidation rate by peroxidase. As mentioned earlier, the presence of metallic ions, also, alters the pH of the anthocyanin pigment and results in color deterioration.

Storage. Prolonged storage of fruits with red or red violet pigments is accompanied by bleaching of some pigments and the development of a red-brown and finally a brown color (Meyer, 1960). Glidden (1953) found the greatest factor in the deterioration of color of the pigment appeared to be the temperature of storage. Grommeck et al. (1964) also reported that the temperature definitely affects the reaction rate, with the rate increasing rapidly as the temperature is raised until a maximum rate is reached between 60-70° F. Kertesz et al. (1948) and Meschter (1953), and Daravingas et al. (1965) found the effect of increasing storage temperature and/or as well as duration of storage significantly reduced the anthocyanin pigments of strawberry preserves and canned raspberries.

Preservation of Cherries

Canned Cherries

The exact beginning of the cherry industry is unknown. Marshall (1954) reported that in 1909 approximately 2,200 tons of red cherries were canned; and this was probably the earliest in commercial canning of substantial portions. The limiting factor in the canning of red cherries was, and still is the factory capacity. Cherries ripen and are harvested in a given area in about two weeks, and if the plant could not handle the crop in this time, part of the cherries were wasted.

Red cherries that are to be canned are picked without stems to facilitate both harvesting and handling at the factory (Marshall, 1954). They are soaked in tanks containing cold water during transport from the orchard to the factory where they are pitted and canned. The generally accepted practice of soaking red cherries in tanks prior to pitting was developed by W. R. Kappler in 1918 (Marshall, 1954). This process made it possible to keep the cherries from spoiling for a longer time and caused them to become more turgid so that they pitted without much flesh clinging to the pit. However, the exact effect depends on the quality of the fruit. Marshall (1954) reported unbruised cherries soaked in water for various lengths of time increased in both weight and firmness and decreased in both soluble solids and acid content. Bruised cherries, however, did not gain sufficiently in weight and lost substantial quantities of soluble solids and acids. A study by Bedford et al. (1957) indicated the firmness and quality of the canned product could be improved by soaking the cherries in a calcium salt solution and by canning with added calcium salt.

Even though cherries that are packed for dessert purposes are canned in sirup, the cherries packed as pie stock are canned in water, thus most of the pitted red cherries are water-packed (Marshall, 1954). Weckel et al. (1959) found processing red sour pitted cherries in sirup rather than in water enhances certain qualities such as color, flavor, and firmness of fruit. Bedford et al. (1957) reported results from taste panel evaluation of pies indicated canning with 0.5, 1.0, 1.5 and 2.0 ounces of sugar or 10, 15, 20 and 25 per cent sugar sirup to each No. 2 can of sour cherries made the product more acceptable. Griswold (1944), also, found Montmorency cherries packed in water compared unfavorably with those packed in 50 per cent sirup in respect to palatability, brightness of color and texture. Even the addition of 0.5-1.0 ounce (2.5-5 per cent) of sugar to each No. 2 can of cherries increased the firmness and brightness and improved the palatability over cherries packed in water (Marshall, 1954).

Frozen Cherries

The first freezing of cherries was done by pie bakers at market centers, in the original fresh fruit crate (Rogers, 1940). In 1921, cherries were first frozen in barrels. At first no sugar was used but, gradually, it was learned that a combination of five parts of cherries to one of sugar improved the color, flavor, and texture (Rogers, 1940). However, additional sugar and a prolonged period of freezing resulted in excessive juice. Tressler (1944) found if the proportion of fruit to sugar is greater than 5 to 1, the color and quality may not be protected.

Today most frozen cherries are packed in thirty pound tins. Bakers and preservers are still the chief sales outlet for the frozen cherry although sales to frozen pie processors are gaining steadily (Great Lakes Report, 1954).

Processing. Handling of cherries is of even greater importance for cherries that are to be frozen than to be canned. Bruised cherries and cherries broken up by faulty pitting are readily detected in the frozen pack (Marshall, 1954). Pitting of cherries aggravates the oxidation problem and thus makes it essential to reduce the time from the initial factory handling to freezing to a minimum (Marshall, 1954).

Although the sirup pack has been shown to have many advantages over a dry sugar pack, the dry sugar pack is still generally preferred because most frozen cherries are intended for the baking trade where a product with a maximum drain weight, or a minimum juice is desired (Marshall, 1954). In contrast, Bedford et al. (1962) reported freezing cherries in sirup resulted in higher drained weights than the dry sugar pack. In this study the drain weights increased as the sirup concentration increased, reaching a maximum with 35-40 per cent sirup solutions. There is some difference of opinion, however, as to the best concentration of sirup for cherries frozen for dessert purposes. Joslyn (1934) found 40 per cent sirup to be satisfactory, while Loutfi (1951) and Diehl et al. (1930) recommended 55-60 per cent concentration. At the present time packers are using a 50° Brix sirup.

During freezing and thawing, cherries are subjected to browning or oxidation, thus resulting in a produce of poorer flavor and color. In the following paragraphs the effect of freezing on color, texture, and palatability will be reviewed.

Color. Gudagni et al. (1958) found the most readily visible change in cherries stored at 20° F was discoloration or browning of the fruit exposed to the headspace atmosphere. The degree of severity of this enzymatic discoloration was found to depend on the amount of sirup coverage, storage temperature, and length of storage. During storage there is an actual loss in red anthocyanin pigments as well as oxidation of other tannin-like phenolic compounds which are converted to melanins (Gudagni et al., 1958). However, the small amount of surface browning does not appear to be of practical importance when the entire can content is mixed and prepared for pies in the usual manner (Gudagni et al., 1963). In contrast, Loutfi (1951) found there was an increase in the color intensity of the frozen product rather than a discoloration. He hypothesized that during the freezing procedure, in the presence of sugar, leucoanthocyanin were converted to the red anthocyanin pigment.

Texture. Gudagni et al. (1963) and Gee et al. (1957) found toughening of frozen Montmorency cherries was greatly influenced by storage time and temperature. They reported firmness of frozen cherries stored at 10-30° F increased rapidly with time, but was stable at -10° F. Toughening (increased firmness) did not appear to be related to sugar treatment of cherries. Siruped and untreated control samples gave the same tenderometer values after storage at -10° F (Gee et al., 1957). Therefore, the changes in texture were attributed to pectinesterase action of pectin diesterfication and the formation of a calcium pectinate gel, from calcium present in the fruit tissue combining with carbonyl groups, when cherries are not frozen solid as they are at -10° F (Gee et al., 1957).

Palatability. In a study by Guadagni et al. (1958) the most detectable organoleptic change was an increase in firmness. The flavor quality factor closely paralleled firmness changes. The color curve indicated little or no difference between controlled and the stored samples up to six to eight weeks of storage at 20° F. Therefore, cherries can be held for at least one year at 0° F and about six months at 10° F without significant changes in color or flavor scores in pies (Guadagni et al., 1963).

Individual Quick Frozen Cherries

Rogers (1940) stated individual quick frozen cherries (IQF), frozen by cold air, spray, or immersion, were unquestionably superior to frozen cherries for providing a greater yield as a pie filler. He also stated, however, that IQF cherries do not retain their original bright red natural color as well as cherries packed in either the barrel or thirty pound tin and therefore the idea of quick freezing individual cherries was abandoned.

In a study of the color of cherries by Labelle et al. (1966) the combined browning and loss of redness was very noticeable in IQF processed cherries. Mayak (1965) reported the most readily observable changes in pitted red cherries, IQF processed without any pretreatments or packing medium, were the loss of red color and browning of the flesh. However, when the cherries were pretreated with SO_2, color loss decreased. In his study cherries treated with 1000 ppm SO_2 showed the least color loss, followed by those treated with 500 ppm SO_2. Therefore, sulfur dioxide treatments could be used to prevent enzymatic and oxidative color destruction and browning during freezing, frozen storage and subsequent thawing (Bedford, 1967). However, additional research is needed on the color, texture, and palatability characteristics of the cherries before the process can be used for commercial application.

Dehydrated Cherries

The cherry industry was interested in other methods of preservation which would provide wider distribution and consumption of its product. Therefore, preliminary investigations on cherry dehydration were initiated by the Michigan Agricultural Experimental Station in 1943 and continued in 1944. The investigation of 1943 indicated the chief objections to dehydrated cherries were inability to rehydrate sufficiently and color deterioration following any considerable length of storage (Alderman *et al.*, 1945). In addition, dehydration has not been able to compete economically with preservation by canning and freezing (Marshall, 1954). Although sun drying is cheaper, it is less desirable than heat dehydration; for heat dehydration enables more rapid and controlled drying and the production of a product of much higher quality (Mrak et al., 1943).

Color. Red tart cherries tend to turn brown or become oxidized on exposure of the flesh to the air. The application of heat, in the process of dehydration, causes further discoloration and results in an unattractive reddish-brown product (Alderman et al., 1945).

Appearance. Dehydrated cherries may attain a slight raisin-like taste and appearance (Mrak et al., 1943). In Alderman et al. (1945), study of the appearance of dehydrated cherries did not compare favorably with the appearance of fresh, canned or frozen cherries. However, they reported that dehydrated cherries do compare favorably with products prepared with other types of dried fruits, such as raisins, dates, or figs. The dried cherries were compared in the following products: muffins, coffee cakes, tea scones, cookies, and cakes. In all cases the cherries had better color and flavor scores if cut in halves or thirds and rehydrated in a double boiler for 15 minutes.

Utilization of Sour Cherries

There has been a slight decrease in the proportions of total commercial crops that were utilized by canning, and an increase in those utilized by the freezing industry (Table 1). In the years of 1962 to 1966, an average of 44 per cent of the total tart cherry sales was utilized by the canning industries and 51 per cent by the freezing industry (Table 1). The canned cherries may be packed in sirup for dessert purposes or in water for pie stock. Frozen cherries are mainly packed for institutional use; however, the use of frozen cherries in unbaked frozen fruit pies for retail sale has been increasing. Cherries are, also, utilized for such other processing as the marketing of wines, juices, preserves, and candied cherries (Marshall, 1954).

Frozen Pies

Commercially produced, unbaked fruit pies have met wide consumer acceptance and their retail sales have shown a rapid increase. Recently studies have been conducted on the storage temperature and time, and effect of defrosting on the quality of frozen pies.

Kulp et al. (1962) reported a freezing time up to twenty-eight hours had no effect on the quality of crust or filling. Pratt (1955) and Kulp et al. (1962) found that frozen pies should be held at 0° F or below. Gudagni et al. (1963) stated, temperatures above 10° F were more detrimental to the quality of the fruit filling than the pastry. Also, temperature fluctuation should be minimal during transportation and storage, in order to maintain the highest quality possible. Pratt

(1955), Kulp et al. (1962), and Fanelli et al. (1961) recommended baking frozen pies without defrosting, for defrosting of any degree adversely affects the quality of the pies.

Objective Measurements

Objective evaluation offers a means of precise measurement of quality characteristics and reproduceability of results under conditions which might affect the reliability of taste panel members. However, the usefulness of objective measurement is, to some extent, contingent upon reasonable agreement with sensory evaluation (Funk et al., 1965). Thus, it is of primary importance that objective methods be developed which will provide a true measurement of the particular quality factor under study (Funk et al., 1965).

Allo-Kramer Shear Press

The Allo-Kramer shear press has been used to measure textural quality of meat, poultry, jellies, fruits, vegetables, and baked products. The operational principles of the shear press were reviewed and discussed by Brown (1964), Endres (1965), Parks (1966) and Wolfe (1967).

In a study by Kramer et al. (1951) and Kramer (1952) high coefficient of correlation between shear press measurements and sensory evaluation of canned lima beans and sweet corn were obtained. Kramer et al. (1953), also, reported shear press measurements of raw peas correlated significantly with panel scores on canned peas. Shallenberger et al. (1963) and Wiley et al. (1960) found a high correlation of panel scores for firmness of canned slice apples with shear values. Sweeney et al. (1962), also, reported that shear press values for grapefruit, pineapple, raspberries, and strawberries agreed with panel texture scores. However, shear values for peaches were lower than expected on the basis of the panel texture score. Kramer et al. (1954) found the measurement of maturity of raw, canned, and frozen lima beans by the shear press more reliable than taste panel evaluation. However, Sather et al. (1963) reported that there was no correlation with shear resistance and appearance scores of pears.

Color Measurements

The Hunter color and Gardner color-difference meter have been used with food products to obtain instrumental color measurements which will correlate with a visual estimate of color. Use of the instrument was reviewed by Endres (1965), Parks (1966), and Wolfe (1967).

Tinsley et al. (1956) and Robinson (1961) found good correlation between Hunter color-difference meter measurements and subjective color evaluation. Tinsley reported that with sensory grading of color it is difficult to eliminate effect of factors other than color. In his study the appearance of raspberry samples determined whether the sample scored high or low within a grade. Sweeny et al. (1962) reported high correlations with taste panel scores and Gardner color measurements. The bright red to extremely dark red range of color in strawberries and raspberries were shown by both the wide ranges in color-difference meter L and a_L values and in panel scores. Gudagni et al. (1957) and Livingston (1959) reported significant correlations between Hunter and Gardner a_L values and the subjective estimation of color difference in strawberries. The relative redness values measured by the Hunter meter were very similar to changes which enable visual observers to detect color differences in frozen strawberries (Gudagni et al., 1957). Sather et al. (1963), also, found significant correlation with appearance and Hunter a_L readings of canned pears.

EXPERIMENTAL PROCEDURE

This research was initiated to determine the differences in quality characteristics, if any, among frozen, canned, individual quick frozen (IQF) and dried Montmorency cherries. The cherries were harvested from the same trees to minimize factors known to affect quality (climate, fertilizer, etc.).

Design of Experiment

This study was designed to determine the effect of canning, freezing, individual quick freezing, and drying of cherries on the color, texture, and palatability of pie fillings. The investigation was also designed to determine the effect of the addition of commercial red food coloring on acceptability of dried cherries in pies; to determine the effect of sodium bisulfite treatments on the color and quality of dried cherries; and to compare the quality of dried cherries in pies which have been frozen and stored at -23.3° C, for two weeks, with freshly prepared pies made with dried cherries.

Six replications of each variable were prepared and submitted to sensory evaluation and objective measurement of quality characteristics. All data was subjected to the appropriate statistical analyses.

Ingredient Procurement

Pastry Formula Ingredients

Common lots of cake flour, bread flour, salt, and shortening were obtained from the Michigan State University Food Stores. The flours, salt, and shortening were weighed to the nearest gram on a Toledo torsion balance, 5-Kilogram capacity.

The pastry was made in seven batches, each consisting of 4536 grams cake flour, 1734 grams bread flour, 3525 grams shortening, 136 grams salt, and 1320 milliliters of water. The flour and salt were placed in the 12-quart bowl of the Hobart mixer, model A-200, and blended with a paddle attachment for 2 minutes. A mixing period of 2 minutes at 70 rpm was used to blend the shortening with the flour. Water was mixed into the shortening-flour mass for 2 minutes at 70 rpm. The pastry was placed on a moderately floured board and folded 50 times.

Rolling was done by hand with an 14-1/2-inch rolling pin, on a 24 × 18-inch board provided with cleats 3/16-inch high. Cake flour was used to flour the board and rolling pin. The rolled crust was cut with a 9-inch pie cutter. Twenty-four single crusts, each separated with freezing paper, were placed in 11-3/4 × 11-3/4 × 7-inch cardboard boxes, and frozen and stored at -23.3° C until used during the following three week cherry pie evaluation period. The boxes were used to protect the pastry against crushing and breaking during storage.

Processing of Cherries

Montmorency cherries grown and harvested commercially with a mechanical harvester from southwest Michigan were used. The cherries were transported in an ice box by truck to the Michigan State University Food Science laboratory, and on arrival were weighed and placed in soaking tanks with running water at 13.9° C. The cherries were delivered to the laboratory within 2 hours after harvest and were soaked for 4 hours prior to processing. The cherries were pitted in a Dunkley cherry pitter of pilot plant capacity.

Canning. Twelve ounces of pitted fruit were put into No. 303 cherry enamel cans, covered with boiling water, exhausted 6 minutes, sealed, processed in boiling water for 8 minutes, cooled and stored at 4° C.

Freezing. Sixty-four ounces of pitted fruit were placed in a plastic bag, 13 ounces of dry sugar added, and bags sealed and rotated to mix fruit and sugar and then frozen and stored at -20.6° C.

IQF. Pitted cherries were transferred into a 0.2% $NaHSO_3$ solution in a 10-gallon stainless steel kettle and held for 1 minute. The treated fruit was transferred to a perforated dehydrater tray, about 2 cherries deep, drained 5 minutes and frozen in an air blast at -20.6° C. The frozen fruit was placed in 30 pound tins and stored at -20.6° C.

Dehydrated. The cherries to be dehydrated were processed two ways; untreated or pretreated with a 0.5% $NaHSO_3$ solution dip.

Untreated. Pitted cherries were placed one layer deep on a perforated dehydrater tray and dried.

SO_2 treated. Pitted cherries were dipped into a 0.5% $NaHSO_3$ solution for 1 minute, transferred to perforated dehydrater tray and dried.

The cherries were dried in a Proctor Schwartz dehydrater, with partial through air flow. A programmed air temperature drop was used. Initial dry bulb temperature was 93° C. The cherries were dried for 1 hour at this temperature, followed by 1 hour at 88° C, 1 hour at 77° C, and finished at 68.3° C. The drying time was about 10 hours to reduce the moisture content to about 25%.

Packaging and storage. The processed cherries were transferred to the Home Economic Research laboratory prior to initiation of the investigation. Upon arrival, the dried cherries were portioned into appropriate amounts, heat sealed in heat sealable polyester pouches, and stored at 4-5° C until used. The canned cherries were stored at room temperature, and the IQF and frozen cherries, left in original containers, were held at -23° C until used.

Cherry filling ingredients. To eliminate any possible variation in ingredients, the sugar, salt, and starch were each obtained from common lots. The waxy-maize starch (Polar Gel 5) was furnished by the American Maize-Products Company and the sugar and salt were purchased from a local distributor.

The sugar and starch were weighed to the nearest gram on a Toledo torsion balance, 5-Kilogram capacity, and salt was weighed to the nearest 0.1 gram on an 800-gram capacity torsion balance. Preweighed sugar, salt, and starch were then packaged in closed polyethylene bags, and stored at room temperature.

Commercial food coloring source. Two commercial certified FD&C colors, Red #2 (Amaranth) and Red #4 (Ponceau Sx) were used as coloring agents. Three grams of each dye, weighed to the nearest 0.1 gram on the torsion balance, 800-gram capacity, were added to two 100-milliliter volumetric flasks, and dissolved in 90 ml of distilled water on a steam bath. The dyes were cooled, brought to volume, stoppered, and held at room temperature until used.

Basic Formula

The formula used in this study was developed in the laboratory prior to the investigation. Pie fillings were prepared according to the formulas given in Table 3.

Table 3. Formula used in the preparation of cherry pie fillings.

Ingredients	Type of cherry					
	Frozen	IQF	Canned	Dried cherry variable		
				No SO_2	SO_2[a]	Color added
	g	g	g	g	g	g
Sugar	40	400	400	400	400	400
Starch[d]	66	66	66	66	66	66
Salt	4	4	4	4	4	4
Cherries	2160	1800	1800	318	337	337
Distilled water				1482	1463	1461
FDC Red #2[b] soln.						1.0 ml
FDC Red #4[c] soln.						1.0 ml

[a]Same formula was used for the frozen dried cherry pies variable.

[b]Amaranth (3%), National Analine Division, 40 Rector Street, New York 6, N. Y.

[c]Ponceau Sx (3%), National Analine Division, 40 Rector Street, New York 6, N. Y.

[d]Polar Gel 5, American Maize-Products Company, Roby, Indiana.

The formula was varied according to the type of processed cherries used, to compensate for differences in moisture of cherries, for the addition of sugar to frozen cherries, and liquid coloring to the dried cherry variables. The exact amount of moisture was determined for each type of cherry by using the AOAC vacuum oven method (1955). The following moisture percentages were based on an average of four readings:

Frozen	Canned*	IQF	SO_2 Dried	No SO_2 Dried
76.44%	88.51%	85.33%	15.17%	19.76%

*After draining for 5 minutes.

The moisture content of the canned cherries remained fairly constant, regardless of the length of drainage time, after 5 minutes. This is due to water bound within the tissues. Therefore, the moisture content of the canned cherry pies was higher than the other pie variables investigated in this study. The amount of water added to the dried cherries was sufficient to make them equivalent to the moisture content of the IQF cherries. The IQF moisture content was used as the standard since this type of processed cherry had neither the addition of water nor sugar. The moisture content of the frozen cherries was similar to IQF when corrected for sugar solids.

Method of Preparation

A day prior to preparation, the IQF cherries were weighed, to the nearest gram on a Toledo torsion balance, 5-Kilogram capacity, into a 3-quart bowl and covered with Saran. The pre-weighed frozen and IQF cherries were then thawed overnight at 4-5° C. The canned cherries were drained in a mesh strainer (24 wires per inch) for 5 minutes and weighed to the nearest gram on a Toledo torsion balance, 5-Kilogram capacity, prior to pie preparation.

Preparation of Cherry Filling

To insure even distribution of dry ingredients, the previously weighed starch, sugar, and salt were dry-blended using a paddle attachment in a 5-quart bowl, Hobart model K-5, for two minutes at 56 rpm. The cherries, cherry juice or distilled water and dry ingredients were blended with a wooden spoon in a 3-quart aluminum saucepan. The mixture was cooked to 40° C on a 7-1/2-inch surface burner set on high. To avoid scorching the heat was then reduced to medium and the mixture was cooked until it thickened and boiled for 15 seconds. Stirring was controlled so that the cherry filling received 6 stirs every five minutes until it began to thicken, then it received three stirs every minute to the end of the cooking period. The thickened mixture was immediately removed from the source of heat. In the preparation of the artificially colored dried cherry filling, each of the coloring agents was measured with a one milliliter volumetric pipette and blended into the cherry mixture at this time. The filling was transferred immediately to a 5-quart Hobart mixing bowl, covered with Saran wrap and then stored at refrigerator temperature 4-5° C for 18-24 hours.

Assembling of the Pie and Baking Procedure

Pre-rolled pastry was removed from the freezer, thawed, and placed in 9 X 1-1/4-inch aluminum pie pans. The cherry fillings were removed from the refrigerator and the pH was recorded. Using a 5-Kilogram capacity Toledo torsion balance, 950 grams of cherry filling were weighed into each of two pastry lined aluminum pie pans. The filling was covered with a top crust and the edges were turned under and crimped. A 4-inch slit was cut in the center of the sealed crust to permit the escape of air and steam. Three variables (6 pies) were baked at the same time. The pies for sensory evaluation and objective measurements were baked on separate shelves. The position of the pies in the oven was randomized by successive rotation between the two shelves every baking period. The pies were baked in an ECTO forced convection oven, model 186-A, for 40 minutes at 232° C.

Frozen Dried Cherry Pie Procedure

The frozen dried cherry pie filling was prepared in the same manner as previously described. The filling was stored in a 5-quart Hobart mixing bowl at 4-5° C until it cooled to 25° C. The pH was recorded and the pies were assembled. The pies were immediately frozen at -30.6° C, which took approximately two hours. After freezing, the pies were individually wrapped in freezing paper and held at -23.3° C until baked. When the frozen pies were removed from the freezer, a 4-inch slit was made in the sealed crust, and the pies were baked in an ECTO forced air oven, model 186-A, at 232° C for 60 minutes.

Preparation of Samples

The two coded pies from each replication of each variable were allowed to cool for two hours before cutting for evaluation. One of the two pies of each replication was used for objective evaluation and the other for taste panel evaluation. The top crust was carefully removed from the pie to be used for objective measurements and discarded. The pie was divided into thirds and cherry filling from each of the sections was spooned into three 70-mm diameter × 50-mm high pyrex crystallizing dishes for color measurements. The same cherry filling was then used for shear press measurements.

To obtain identical slice size and randomization for sensory evaluation eight equal sections were marked on the pie pans and the sections were numbered 1 through 8 prior to the investigation. Pie slices designated for taste panel members were rotated according to a similar pattern used by Funk et al. (1965), as shown in Figure 1.

1st Replication

1. Panel member 1
2. Panel member 2
3. Panel member 3
4. Panel member 4
5. Panel member 5
6. Panel member 6
7. Panel member 7
8. Panel member 8

2nd Replication

1. Panel member 8
2. Panel member 1
3. Panel member 2
4. Panel member 3
5. Panel member 4
6. Panel member 5
7. Panel member 6
8. Panel member 7

Figure 1. Sequence for cutting and testing the slices of cherry pies for taste panel evaluation.

Subjective Evaluation

An eight member taste panel was utilized to determine the acceptability of the color, appearance of cherry, viscosity of sauce, tenderness of skin, texture of flesh and flavor of cherries processed by various methods. All attributes were scored on a 7-point rating scale. Judgment as to whether the product was acceptable or not was indicated and additional comments were noted. The cherry pie score card appears in the appendix.

Three training sessions prior to evaluation of the pies were held in order to check the suitability of the terms used on the score card, to acquaint the panel members with the product, and to allow them to ask questions. Directions for taste panel members appear in the appendix. In addition, the panel members were directed to remove the top crust before evaluation. All samples were coded according to predetermined randomized numbers. Sectors for each pie were placed on 7-1/2-inch randomly numbered white plates. Each plate was tightly wrapped with Saran to prevent dehydration until evaluation by the panel members approximately 1-1/2 hours later. There were fourteen test periods with three samples presented and evaluated individually each period. All evaluations were carried out under 15-watt cool fluorescent lighting.

Objective Measurements

Objective tests were used to evaluate pH, color, and tenderness of the various processed cherries. Prior to baking, pH determinations were made on the cherry fillings. Baked pies were evaluated for cherry color and tenderness.

pH of Cherry Filling

The pH determinations were made on the cherry filling with a Beckman Zeromatic pH meter equipped with Calomel and glass electrodes. The filling was placed in conventional pyrex 5-ounce baking cups prior to assembling the pies and pH was recorded.

Color Measurements

Color of the baked cherry filling was measured using a Hunter Color-difference meter, model D-25. The instrument was standardized with a red tile (L, 25.0; a_L, +27.8; b_L, +15.6) covered with an optical lens in preparation for determination of L (lightness), a_{L+} (redness) and b_{L+} (yellowness) values of the cherry samples.

Samples were taken from three sections of the pie and each sample was placed in a separate 70-mm diameter × 50-mm high pyrex crystallizing dish. The top of the crystallizing dishes were leveled off and the flat surfaces were covered with special optical lens (3 in. × 4 in. × 1/8 in.). The assembly was placed under the viewing area and readings were recorded. Each value reported represents an average of three readings.

Tenderness of the Cherries

Tenderness was measured using the standard shear-compression cell of the Allo-Kramer shear press, model SP-12, equipped with an electronic recorder, model E-2 EZ. The 3000-pound proving ring, 10-pound range, 25-pound pressure and 30-second downstroke were used for this measurement.

After color measurements were recorded, 1/2 inch of the top layers of cherries was removed from the crystallizing dishes; and 100-gram samples were weighed to nearest gram, from each dish, into conventional custard cups on an 800-gram capacity Torsion balance. Also during weighing, the cherry pieces were examined for pits by injecting a No. 9 sewing needle into the fruit flesh; any sample containing a pit was not used. The weighed samples were removed from the cups with a rubber spatula, and placed in the lower assembly of the cell. The values for tenderness were recorded on the chart paper as the upper assembly cell sheared through the cherry pieces. The sections of the cell assembly were thoroughly rinsed with lukewarm water between each evaluation.

Tenderness of the cherries was determined using two factors, maximum force and area-under-the-curve. Maximum force needed to shear through the cherry samples was calculated as

$$\frac{\text{Maximum graph reading} \times \text{range (\%)} \times \text{ring}}{\text{sample weight}}$$

Each maximum force value was based on an average of three trials. To compute area, the graph curve was carefully cut out and weighed on a Mettler balance, Model H-15. The area was computed by multiplying the weight of the graph by a determined conversion factor 174.2 as discussed by Funk et al. (1965). An average of three samples was recorded for each replication.

Analysis of Data

Subjective and objective data were summarized and evaluated by the CDC 3600 computer at Michigan State University. The Rand Routine was used to calculate analysis of variance for types of cherries, judges, and comparison of frozen dried vs. dried cherry pies. The BAStat Routine with a transformation subroutine was employed to determine standard deviations of the means and simple correlation coefficient. Significant differences among types of cherries, individual treatment combination and mean sensory scores and judges were evaluated through the use of the Studentized range test (Duncan, 1957).

RESULTS AND DISCUSSION

The purpose of this investigation was to determine the effect of four different types of processing methods--freezing, canning, individual quick freezing, and dehydration--on the quality characteristics of Montmorency cherries in pies. In addition, studies were made with dried cherries to determine the effect of artificial coloring on their acceptability in pie filling; the effect of sodium bisulfite treatment on color and quality; and the suitability of dried cherries in frozen pies. Objective and sensory data were examined to ascertain the quality of the cherries used in each variable. Methods were developed in the laboratory to control all other variables which might affect the quality of the product.

Subjective Evaluation of Cherry Pie Fillings

The color, appearance, viscosity of sauce, tenderness of cherry skin, texture of cherry flesh, flavor, and acceptability of cherry pie fillings were evaluated by an eight member taste panel. A 7-point rating scale was used, with 7 being the most desirable score. Replicate averages, cherry process means, and standard deviations for sensory evaluation of cherry processes are included in the Appendix. The data analyzed for variance indicated very highly significant differences among cherry pie filling attributes of the sensory test (Table 4). Therefore, the data were further subjected to a Studentized range test to determine significant differences among cherry process means (Table 5). Simple correlation coefficients for the seven cherry filling attributes were derived (Table 6).

Color

Analysis of cherry process means (Table 5) indicated that the colors of frozen and IQF cherry pie fillings were scored significantly higher than the colors of all other variables. The dried cherry pie filling to which red food coloring (FDC #2 & #4) had been added scored significantly higher for color than the other dried cherry pie variables and obtained similar color scores to those for canned cherry pie fillings (0.1 per cent level). There were highly significant differences between the color of 0.5 per cent sodium bisulfite- and nonsodium bisulfite-treated-dried cherry pie fillings. However, they both received significantly lower color scores than the other pie filling variables ($p \leq 0.01$).

Kodachrome pictures were made of the fruit prior to pie preparation and of the pie filling after baking. Figure 2 shows the

Table 4. Analysis of variance for determining the effect of cherry process on the subjective evaluation of cherry pie filling attributes.

Source of variance	Degree of freedom	Mean square						
		Color	Appearance	Viscosity	Tenderness of skin	Texture of flesh	Flavor	Acceptability
Cherry process	5	13.02***	8.98***	1.01***	1.81***	3.15***	3.38***	0.62***
Replication	5	0.10	0.09	0.10	0.28	0.06	0.17	0.00
Error	25	0.19	0.07	0.07	0.22	0.18	0.17	0.03
Total	35							

***Significant at the 0.1 per cent level of probability.

Table 5. Studentized multiple range test for sensory attributes.[a]

Color

Frozen	IQF	Dried Coloring added	Canned	Dried SO_2 treated	Dried No SO_2
0.1% Level:					
6.1	5.7	4.5	4.3	3.5	2.1
1% and 5% Level:					
6.1	5.7	4.5	4.3	3.5	2.1

Appearance

Frozen	IQF	Canned	Dried Coloring added	Dried SO_2 treated	Dried No SO_2
0.1% Level:					
6.3	5.6	3.9	3.8	3.5	3.4
1% Level:					
6.3	5.6	3.9	3.8	3.5	3.4
5% Level:					
6.3	5.6	3.9	3.8	3.5	3.4

[a]Means underscored by the same line are not significantly different (Duncan, 1957).

Table 5. Continued.

Viscosity of Sauce

	IQF	Dried Coloring added	Canned	Frozen	Dried SO_2 treated	Dried No SO_2
0.1% Level:	6.8	6.5	6.3	6.2	5.9	5.7
	———	———	———	———		
		———	———	———	———	
			———	———	———	———
1% Level:	6.8	6.5	6.3	6.2	5.9	5.7
	———	———				
		———	———	———		
			———	———	———	
					———	———
5% Level:	6.8	6.5	6.3	6.2	5.9	5.7
	———	———				
		———	———	———		
				———	———	
					———	———

Tenderness of Skin

	Canned	Frozen	IQF	Dried SO_2 treated	Dried Coloring added	Dried No SO_2
0.1% Level:	6.6	6.2	6.0	5.6	5.3	5.2
	———	———	———	———		
		———	———	———	———	———
1% Level:	6.6	6.2	6.0	5.6	5.3	5.2
	———	———	———			
		———	———	———		
			———	———	———	———
5% Level:	6.6	6.2	6.0	5.6	5.3	5.2
	———	———				
		———	———			
			———	———		
				———	———	———

[a]Means underscored by the same line are not significantly different (Duncan, 1957).

Table 5. Continued.

Texture of Flesh

Frozen	IQF	Canned	Dried Coloring added	Dried SO_2 treated	Dried No SO_2
0.1% Level:					
6.3	5.8	4.9	4.8	4.7	4.5
1% and 5% Level:					
6.3	5.8	4.9	4.8	4.7	4.5

Flavor

Frozen	IQF	Canned	Dried Coloring added	Dried SO_2 treated	Dried No SO_2
0.1% Level:					
6.0	6.0	5.5	5.5	4.8	4.1
1% and 5% Level:					
6.0	6.0	5.5	5.5	4.8	4.1

Acceptability (%)

Frozen	IQF	Dried Coloring added	Canned	Dried SO_2 treated	Dried No SO_2
0.1% and 1% Level:					
98	97	78	75	37	20
5% Level:					
98	97	78	75	37	20

[a]Means underscored by the same line are not significantly different (Duncan, 1957).

Table 6. Significant correlation coefficients for cherry filling attributes evaluated by subjective evaluation.

Cherry filling attributes	Color	Appear-ance	Viscosity	Tender-ness of skin	Texture of flesh	Flavor	Accept-ability
Color of cherry		.859***	.609***	.519**	.839***	.863***	.897***
Appearance of cherry	.859***		.418*	.472**	.871***	.698***	.754***
Viscosity of sauce	.609***	.418*			.387*	.692***	.709***
Tenderness of skin	.519**	.474**			.484**	.498**	.532**
Texture of flesh	.839***	.871***	.387*	.484**		.643***	.703***
Flavor	.863***	.698***	.692***	.498**	.643***		.890***
Acceptability	.897***	.754***	.709***	.532**	.703***	.890***	

*Significant at the 5 per cent level of probability.

**Significant at the 1 per cent level of probability.

***Significant at the 0.1 per cent level of probability.

relative differences in the color and appearance of the fruit from different processing treatments prior to preparation of the pie fillings. The colors of the various cherry pie filling variables evaluated by the judges are shown in Figure 3.

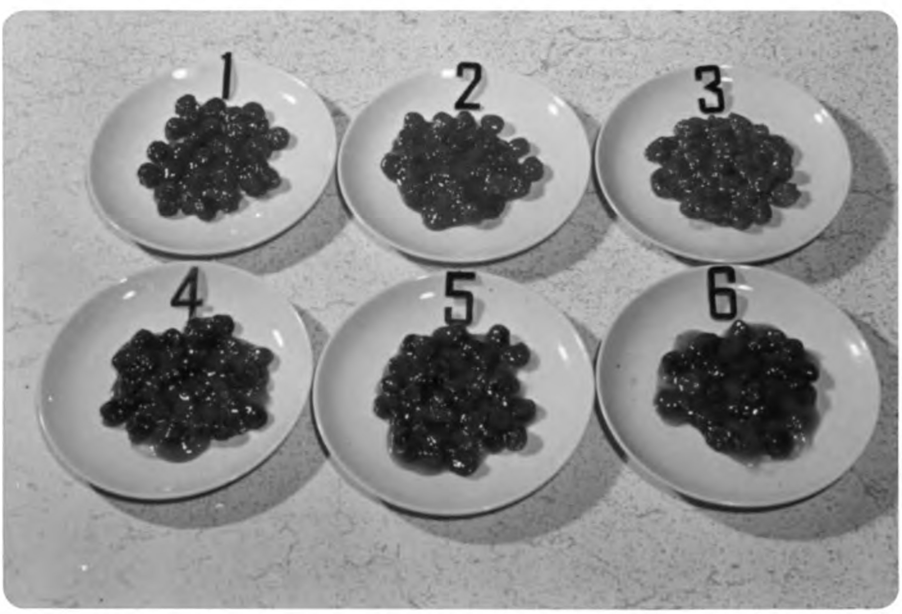
The color of the sodium bisulfite treated IQF cherries was highly acceptable. Mayak (1965) reported that the SO_2 pretreatment of pitted cherries prior to IQF processing decreased red color loss and browning of the fruit flesh whereas untreated fruit lost red color and browned as reported by LaBelle et al. (1966).

The panel members indicated that the color of canned cherry filling had less red color intensity than the frozen and IQF cherries. It is apparent in Figures 2 and 3. The loss of the typical bright red cherry color during canning was reported by Culpepper et al. (1927), Griswold (1944) and Whittenberger et al. (1956). The low color scores given to the dehydrated cherries, by the panel, were due to the occurrence of oxidative browning which produced a light, brownish-red to brown color in the cherries. This was more pronounced in the non-sulfited fruit. Therefore, since considerable browning did occur, the investigator concluded that the treated dried cherries did not receive a proper amount of sodium bisulfite to combine with the quinone and inhibit melanin formation. This color deterioration was described by Alterman et al. (1945) as being one of the chief objections to dehydrated

Key

1. Frozen
2. IQF
3. Canned
4. Dried-SO_2 treated
5. Dried-no SO_2

Figure 2. The color and appearance of five types of processed cherries prior to pie preparation.



Key

1. Frozen
2. IQF
3. Canned
4. Dried-coloring added
5. Dried-SO_2 treated
6. Dried-no SO_2

Figure 3. The color and appearance of cherry pie fillings prepared with frozen, IQF, canned, and dried cherries.

cherries. However, addition of commercial red coloring to the dried cherry pie filling improved the color score. The pie fillings of the other dried cherry variables were light, brownish-red in color as compared to the cherry red color of the colored pie fillings (Figure 3).

Appearance

The appearance of frozen cherry pie filling was scored significantly higher than IQF cherry pie filling, which in turn was scored significantly more desirable than those of the canned and dehydrated cherry fillings ($p \leq 0.001$). There were no significant differences among the appearance of canned and dehydrated cherry pie fillings (0.1 per cent level).

The appearance of canned cherries scored significantly lower than frozen and IQF cherries, due to destruction of the typical, whole cherry character. This destruction occurred during preparation of the pie filling. Therefore, the additional cooking and stirring was disadvantageous to the tender texture of the heat processed cherries. The taste panel members criticized the dried cherry variables for their moderately plump, wrinkled appearance (Figure 3). This is in agreement with the findings reported by Alderman *et al.* (1945).

Viscosity of Sauce

Comparison of cherry processes (Table 5) revealed the viscosity of IQF, dried-colored, canned, and frozen cherry fillings were not significantly different ($p \leq 0.001$). At the 5 per cent level the viscosities of sodium bisulfite-, and nonsodium bisulfite-treated-dried cherry sauces were scored significantly lower than IQF, dried-with-coloring-added, and canned cherry sauces. The lower viscosity scores of pie fillings made with dried cherries may be due to incomplete rehydration even though the dried cherry variable with red food coloring scored significantly higher (1 per cent level).

Tenderness of Cherry Skin

The tenderness of the skin of frozen, IQF, and dried cherry variables were not significantly different at the 0.1 per cent level (Table 5). However, the skin of canned cherries was scored as being significantly more tender than those of the dried cherry variables ($p \leq 0.01$).

Texture of Cherry Flesh

The Studentized range test revealed that the flesh of frozen and IQF cherries were significantly more tender and heavier fleshed than the canned and dried cherry variables (1 per cent level). The flesh texture of the dried cherries was described by the judges as being thin (or lacked fleshiness). This may be due to incomplete rehydration of the cherries during preparation. The flesh of canned cherries was described as being fleshy, but undesirably mushy.

Flavor

There were no significant differences for flavor (Table 5) among frozen, IQF, canned and dried-with-coloring-added cherry pie fillings ($p \leq 0.001$). However, the flavor of sodium bisulfite-, and nonsodium bisulfite-treated-dried cherries were scored significantly different and significantly lower than the other cherry variables at the 1 per cent level. The dried cherries were often reported as being too tart or bitter and the sauce as being too sweet. Therefore, unlike the frozen, IQF, and canned cherries, sugar was not absorbed into the fruit tissues; and thus, there was a contrast between the concentrated tart flavor of the partially rehydrated fruit with the sweet flavor of the sauce. Although the dried cherry fillings with red coloring added were described as being too tart, they received significantly higher scores than the other dried cherry variables; and thus indicating an interrelationship between eye appeal and scoring for flavor. It, also, indicates that the presence of sodium bisulfite at the level used in this experiment did not affect the flavor scores.

Acceptability

Judgment as to whether the product was acceptable or not was indicated by checking yes or no on the score sheet. To determine significant differences the responses were converted to a percentage by dividing the number of positive responses for each replication by the total number of judges (8) and multiplying the quotient by 100.

The acceptability of frozen, IQF, dried-with-coloring-added, and canned cherry pie fillings were not significantly different at the 0.1 per cent level of probability. However, the sodium bisulfite- and nonsodium bisulfite-treated-dried cherry fillings were only acceptable 1/3 and 1/5 of the time ($p \leq 0.001$). Since the fillings made from dried cherries with color added were as acceptable as fillings made from canned or frozen cherries, the investigator concluded color was the major contributing factor to acceptability. The wrinkled, raisin-like appearance and browning were often reported by the panel members as undesirable characteristics of the noncolored dried cherry variables, and may be the reason for their lower acceptability scores.

Correlation between Cherry Pie Filling Attributes

Significant correlation coefficients between cherry filling attributes are included in Table 6. A high positive correlation existed between most attributes (0.1 per cent), with the exception of no correlation between viscosity of sauce and tenderness of cherry skin. However, correlation between these two attributes would not be expected. Thus, sensory evaluations of cherry attributes and the acceptability of cherry pies were highly interrelated.

Analysis of Taste Panel Member Data

To determine variations among the scoring of judges, sensory data for cherry pie attributes were subjected to three-way analyses of variance (Table 7). The analyses indicated significant differences which could be attributed to cherry process and judges, as well as interaction between these factors. There were no significant differences in replications and thus the judges were consistent in their scoring between replications. Although there were significant differences among judges for all sensory attributes, the same general trend held true for significant differences among cherry processes as those indicated in Table 4, with the exception of acceptability. For this factor some of the judges scored IQF and frozen cherry pie fillings significantly different and more acceptable than canned and colored cherry pie fillings made with dried cherries.

The highly significant interactions between cherry process and judge were examined. However, no consistent trend to cause this interaction could be determined. Moreover, the use of the

Table 7. Analysis of variance for determining significant differences among judges.

Source of variance	Degree of freedom	Mean square						
		Color	Appearance	Viscosity	Tenderness of skin	Texture of flesh	Flavor	Acceptability
Total	287							
Cherry process	5	103.31***	70.86***	7.82***	14.33***	25.96***	27.00***	5.16***
Replication	5	0.90	0.96	0.75	2.18	0.46	1.30	0.02
Judge	7	23.01***	27.90***	8.53***	11.81***	19.80***	9.77***	1.38***
CP × Judge	35	2.62***	2.52***	0.89	2.14***	2.91***	2.22***	0.23***
Error	235	0.96	0.65	0.59	0.96	1.11	0.83	0.09

***Significant at the 0.1 per cent level of probability.

interaction mean square as the error term in calculating F value for cherry process means still resulted in very highly significant values.

Objective Measurements

Objective evaluation of color of cherries was determined by the Hunter color-difference meter and cherry tenderness by the Allo-Kramer shear press. Numerical data from these measurements were subjected to analyses of variance. Significant differences were derived by use of the Studentized multiple range test (Duncan, 1957) and correlation coefficients were calculated. Replicate averages for cherry processes, cherry process means, as well as standard deviations for the objective evaluations are included in the Appendix.

Hunter Color-Difference Meter

Analysis of variance for color differences measured by the L, a_L, and b_L values (Table 8) revealed highly significant differences which could be attributed to cherry processing. Comparison of the cherry process means (Table 9) indicated that canned cherries were lighter in color than IQF and sodium bisulfite-treated-dried cherries, which in turn were lighter than frozen, nonsodium bisulfite-treated-dried, and dried cherries with coloring added to the filling (0.1 per cent level). The a_L values indicated that the color of IQF cherry pie fillings were very highly significantly more red than pies prepared with all other types of cherries. The sodium bisulfite- and nonsodium bisulfite-treated-dried cherries were the least red ($p \leq 0.001$). Analysis of b_L values indicated that canned cherries were the most yellow. The yellowness value of the IQF cherries was significantly lower than that of the canned cherries, but higher than the values of the other processed cherries (0.1 per cent level).

Table 8. Analysis of variance for determining the effect of cherry process on the Hunter color-difference meter measurement of cherry pie filling.

Source of variance	Degrees of freedom	Mean squares		
		L Values	a_L Values	b_L Values
Cherry process	5	52.20***	92.78***	16.53***
Replication	5	1.39	0.46	0.18
Error	25	0.56	0.42	0.23
Total	35			

***Significant at the 0.1 per cent level of probability.

The a_L/b_L ratio commonly used to evaluate the redness value of tomato juice was reviewed and discussed by Endres (1965). The following a_L/b_L ratios were calculated for the various processed cherries: Frozen, 2.23; IQF, 2.15; Dried-coloring-added, 2.12;

Table 9. Studentized multiple range test for Hunter color-difference meter measurement.[a]

L Values (Lightness)

Canned	IQF	Dried SO_2 treated	Frozen	Dried No SO_2	Dried Coloring added
0.1%, 1% and 5% Level:					
24.1	19.1	19.0	16.6	16.5	16.4

a_L Values (Redness)

IQF	Canned	Frozen	Dried Coloring added	Dried SO_2 treated	Dried No SO_2
0.1%, 1% and 5% Level:					
24.5	21.2	20.8	20.4	17.1	13.1

b_L Values (Yellowness)

Canned	IQF	Dried SO_2 treated	Dried Coloring added	Frozen	Dried No SO_2
0.1% Level:					
13.2	11.4	10.1	9.6	9.3	8.6
1% Level:					
13.2	11.4	10.1	9.6	9.3	8.6
5% Level:					
13.2	11.4	10.1	9.6	9.3	8.6

[a]Means underscored by the same line are not significantly different (Duncan, 1957).

Dried-SO_2-treated, 1.69; Canned, 1.60; and Dried-no SO_2, 1.52. These ratios indicate that canned cherries are less red in color than frozen, IQF, dried-colored, and dried sodium bisulfite-treated cherries. However, this is in contradiction to the a_L values of canned cherries; thus, in determining the redness of cherries in this experiment the use of a_L/b_L ratio proved to be less accurate than the use of a_L value alone. Although the a_L/b_L ratio was not beneficial for measuring redness of cherry pie filling per se, it may be more accurate when used with plain fruit.

Correlation among the objective and subjective measurement of color. A very highly significant correlation (r = +0.829) existed between the a_L values and sensory evaluation for color. However, there were no significant correlations among L, b_L values and sensory test. Therefore, the a_L value is the most reliable objective measurement of color for cherry pie fillings.

Kramer Shear Press Measurements

Analysis of variance for tenderness (Table 10) as measured by maximum force and area-under-the-curve, indicated that cherry process was responsible for a highly significant

Table 10. Analysis of variance for determining the effect of cherry process on shear press measurement of tenderness of cherries in pie filling.

Source of variance	Degree of freedom	Mean square	
		Force	Area-under-the-curve
Replication	5	0.02	0.03
Cherry process	5	2.78***	1.24***
Error	25	0.05	0.03
Total	35		

***Significant at the 0.1 per cent level of probability.

difference. Comparison of the cherry process means (Table 11) revealed that greater force was needed to shear IQF cherries than pie fillings prepared with all other types of cherries ($p \leq 0.001$). Both the total force and area-under-the-curve values indicated that canned cherries were very highly significantly more tender than the other types of processed cherries. There were no significant differences among the force values of frozen and dried cherry variables (0.1 per cent level).

Table 11. Studentized multiple range test for shear press measurements.[a]

Shear Press Values Based on Maximum Force (lb/g)

IQF	Frozen	Dried Coloring added	Dried No SO_2	Dried SO_2 treated	Canned
0.1%, 1% and 5% Level:					
3.0	2.4	2.2	2.1	2.1	.93

Shear Press Area-Under-the-Curve (cm^2)

Frozen	IQF	Dried Coloring added	Dried SO_2 treated	Dried No SO_2	Canned
0.1% Level:					
2.4	2.3	2.1	2.1	1.8	1.1
1% and 5% Level:					
2.4	2.3	2.1	2.1	1.8	1.1

[a]Means underscored by the same line are not significantly different (Duncan, 1957).

Correlation between shear press and subjective evaluations of cherries. A very highly significant correlation (r = +0.879) existed between the two shear press measurements. However, there was no significant correlation among shear press measurements and sensory evaluation of tenderness of cherry skin. As mentioned previously, appearance and color of cherry samples may have influenced the judges' evaluation of tenderness in this study.

Frozen Dried Cherry Pies

Sodium bisulfite-treated-dried cherry pies were prepared and frozen two weeks prior to baking. These pies were subjected to sensory and objective measurements to determine if the results compared favorably with the test results of the freshly prepared pie fillings made with dried cherries. If an acceptable frozen cherry pie could be prepared from dried cherries, the process could serve as a means of utilizing dried cherries for retail sales and institutional use.

Comparison of Sensory Evaluation of Frozen and Nonfrozen Dried Cherry Pie Fillings

Replicate averages for cherry process, cherry process means, as well as standard deviations for the sensory evaluation of frozen and nonfrozen dried cherry pie fillings are included in the Appendix. Analyses of variance for sensory evaluation revealed no significant differences between the two products (Table 12). Therefore, freezing did not alter the sensory characteristics of dried

Table 12. Analysis of variance for determining the effect of freezing on the subjective evaluation of sodium bisulfite-treated-dried cherry pie fillings.

Source of variance	Degree of freedom	Mean square						
		Color	Appearance	Viscosity	Tenderness of skin	Texture of flesh	Flavor	Acceptability
Cherry process	1	1.23	0.21	0.03	0.32	0.14	1.09	0.26
Replication	4	0.21	0.04	0.03	0.54	0.03	0.09	0.01
Error	4	0.07	0.06	0.04	0.11	0.09	0.07	0.04
Total	9							

cherry pie fillings. However, since both products received low acceptability scores, dried cherries could not be utilized in commercial preparation of frozen pies without further improvements in processing.

Comparison of Objective Measurements of Frozen and Nonfrozen Dried Cherry Pie Fillings

Replicate averages for cherry process, cherry process means, as well as standard deviations for the objective measurements of frozen and nonfrozen dried cherry pie fillings are included in the Appendix. Analyses of variance for objective measurements (Table 13) indicated no significant differences between the two products. Thus, freezing did not alter the color or tenderness of the dried cherry pie fillings.

Table 13. Analysis of variance for determining the effect of freezing on the objective evaluation of dried cherry pie filling.

Source of variance	Degrees of freedom	Mean square				
		Shear press		Hunter		
		Force	Area	L Value	a_L Value	b_L Value
Cherry process	1	0.05	0.06	2.12	0.08	0.00
Replication	4	0.17	0.08	1.05	0.45	0.07
Error	4	0.02	0.02	0.40	0.78	0.27
Total	9					

SUMMARY AND CONCLUSIONS

The primary purpose of this investigation was to determine the effect of canning, freezing, individual quick freezing and drying on the color, viscosity, and palatability of red cherry pie fillings. Secondary objectives included comparison of the quality characteristics of frozen dried cherry pies versus nonfrozen dried cherry pies; determination of the effect of commercial red food coloring on acceptability of cherry pies made with dried cherries; and determination of the effect of sodium bisulfite treatments on the color and quality of dried cherries.

All cherries used in this investigation came from a common lot; standardized procedures were utilized in the preparation, baking, and testing of pie fillings. All data reported are the average of six replications.

Sensory evaluation of cherry attributes were evaluated by an eight member taste panel using a 7-point rating scale, with 7 being the most desirable score. The results of the sensory test indicated that the color of frozen and IQF cherry fillings were preferred over canned and pie fillings made with dried cherries (0.1

per cent level). The color of nonsodium bisulfite-treated-dried cherry fillings scored highly significantly lower than 0.5 per cent sodium bisulfite-treated-dried cherry fillings. Both scored significantly lower than 0.5 per cent sodium bisulfite-treated-dried cherry fillings with red coloring added (0.1 per cent level). Subjective evaluation of appearance revealed that frozen was preferred over IQF cherry filling and both were preferred over the canned and pie fillings made with dried cherries (0.1 per cent level).

The viscosity of the sodium bisulfite-treated- and nonsodium bisulfite-treated-dried cherry fillings scored significantly lower than those of the IQF, dried-with-coloring-added, and canned cherry pie fillings (5 per cent level). There were no significant differences in tenderness of cherry skin of frozen, IQF, and the dried cherry variables (0.1 per cent level). Canned cherries were scored significantly more tender than the dried cherry variables (1 per cent level). The sensory evaluation of texture of cherry flesh revealed that the flesh of frozen and IQF cherries were scored significantly higher than canned and dehydrated cherries (1 per cent level). There were no significant differences for flavor and acceptability among frozen, IQF, canned, and dried-with-coloring-added cherry pie fillings (1 per cent level). The sodium bisulfite-treated- and nonsodium bisulfite-treated-dried cherry pie fillings scored significantly lower for flavor and acceptability than the other variables (1 per cent level).

The Hunter color-difference meter was utilized to determine differences in color of cherry fillings. Analysis of the color data indicated that canned cherries were lighter and more yellow than the other processed cherries (0.1 per cent level). IQF cherry fillings had significantly higher redness values than pie fillings prepared with all other types of cherries. Analysis of the redness values also revealed that sodium bisulfite and nonsodium bisulfite-treated-dried cherries were less red than the other variables (0.1 per cent level). Correlation coefficients were determined between sensory evaluation of color and the Hunter values. Positive correlations were found between Hunter a_L values and the sensory data for color. However, there were no significant correlations among L, b_L values and sensory test.

The Kramer shear press was utilized to determine tenderness of the various processed cherries. Analyses of data revealed that greater force was needed to shear IQF cherries than all other types of processed cherries (0.1 per cent level). There were no significant differences among the force readings of frozen and dried cherry variables (0.1 per cent level). Correlation coefficients were determined between sensory evaluation of texture and the shear press. There were no significant correlations between the two measurements.

Sodium bisulfite-treated-dried cherry pies were prepared and frozen two weeks prior to baking. The baked frozen pies were subjected to sensory and objective measurements and the results were compared with those of freshly prepared pie fillings made with dried cherries. Analyses of variance for both sensory and objective measurements revealed no significant differences between the two products. However, since both products received low acceptability scores, dried cherries could not be utilized in commercial preparation of frozen pies without further improvements in processing.

The results of this investigation indicated that frozen and IQF cherries produced the most desirable pie fillings. Sodium bisulfite-treated- and nonsodium bisulfite-treated-dried cherries were least desirable; however, the addition of commercial red food coloring significantly improved the sodium bisulfite-treated-dried cherry pie fillings. The findings in this study indicated a need for research in the following areas: (1) an investigation to improve dehydration techniques and to determine the effect of pretreatment with higher concentration of sodium bisulfite on color retention in dehydrated cherries; (2) a study to determine more effective methods of rehydrating dried cherries; (3) a study to determine the effect of cherries in other baked products; (4) a study to determine the effect of commercial red food coloring on acceptability of frozen dried cherry pies; (5) to compare sensory attributes of IQF cherry pies with commercially prepared frozen sour cherry pies; and (6) a study to determine the effect of storage on color and palatability of frozen, IQF, canned and dehydrated cherries.

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APPENDIX

GENERAL INSTRUCTIONS FOR CHERRY PIE EVALUATION

1. Please refrain from drinking coffee, eating, or smoking one-half hour before panel evaluation.

2. Please do not give any facial or vocal reactions as you evaluate your samples.

3. The samples will be presented one at a time. Using a red pencil please mark the block which most nearly fits your evaluation of each quality characteristic of the sample.

4. When you have completed the evaluation, turn your score card over and an assistant will replace it with a second sample.

5. Take your time in judging each sample.

6. Rinse your mouth between sample evaluation with the water provided.

7. Three samples will be evaluated during each session.

8. You will be provided with a list of dates for taste paneling.

Figure 4. General instructions for taste panel members.

Table 14. Replicate averages, cherry process means, and standard deviations for sensory evaluation of cherry attributes (7-point scale; 8 judges).

Cherry attribute	Rep.	Processed cherries utilized in pie preparation					
		Frozen	IQF	Canned	Dried-coloring added	Dried-no coloring added	Dried-no SO_2 treatment
Color	1	5.9	5.8	4.0	3.9	4.1	2.3
	2	5.8	4.8	3.6	4.9	3.5	2.0
	3	6.3	6.1	3.8	4.6	4.0	2.0
	4	6.3	6.0	4.6	4.4	3.1	2.0
	5	6.6	5.5	5.0	4.6	3.0	1.9
	6	5.9	5.9	4.6	4.4	3.0	2.4
Mean/standard deviation for cherry processes		6.1 ± 0.31	5.7 ± 0.48	4.3 ± 0.55	4.7 ± 0.33	3.5 ± 0.50	2.1 ± 0.20
Appearance	1	6.0	5.6	3.5	3.5	3.8	2.9
	2	6.1	5.3	4.0	4.0	3.5	3.1
	3	6.4	5.4	3.9	3.8	3.8	3.8
	4	6.5	5.6	4.1	4.1	3.4	3.5
	5	6.6	5.6	3.6	4.0	3.6	3.6
	6	6.3	6.1	4.0	3.6	3.1	3.5
Mean/standard deviation for cherry processes		6.3 ± 0.23	5.6 ± 0.28	3.9 ± 0.24	3.8 ± 0.24	3.5 ± 0.27	3.4 ± 0.33
Viscosity of sauce	1	6.6	6.8	6.3	6.6	6.4	5.8
	2	6.5	6.8	6.5	6.8	5.8	5.1
	3	5.4	6.9	6.3	6.3	5.8	6.0
	4	5.9	6.9	6.0	6.4	5.5	5.6
	5	6.4	6.8	6.3	6.4	5.8	5.8
	6	6.3	6.6	6.4	6.3	6.0	5.6
Mean/standard deviation for cherry processes		6.2 ± 0.45	6.8 ± 0.11	6.3 ± 0.17	6.5 ± 0.20	5.9 ± 0.30	5.7 ± 0.31

Table 14. Continued.

Tenderness of cherry skin	1	5.4	6.1	5.3	4.6	6.0	4.8
	2	6.4	5.6	6.5	5.4	6.3	5.0
	3	5.9	5.9	6.9	5.5	5.6	5.4
	4	6.6	5.8	6.8	5.6	5.3	5.0
	5	6.4	6.0	6.9	5.4	5.8	5.4
	6	6.6	6.4	6.9	5.1	4.3	5.4
Mean/standard deviation for cherry processes		6.2 ± 0.48	6.0 ± 0.27	6.6 ± 0.63	5.3 ± 0.37	5.6 ± 0.70	5.2 ± 0.27
Texture of cherry flesh	1	5.5	6.1	4.5	5.0	5.1	5.3
	2	6.0	5.0	5.0	5.1	4.9	4.4
	3	6.5	6.1	4.3	4.8	4.8	4.5
	4	6.6	5.8	5.0	4.4	4.1	4.1
	5	6.6	5.6	5.1	4.6	4.8	4.4
	6	6.6	6.1	5.4	4.8	4.5	4.0
Mean/standard deviation for cherry processes		6.3 ± 0.46	5.8 ± 0.44	4.9 + 0.41	4.8 ± 0.26	4.7 ± 0.35	4.5 ± 0.46
Flavor	1	6.1	6.3	5.0	5.3	5.0	3.4
	2	5.6	6.0	5.4	6.1	4.3	3.6
	3	5.5	5.6	4.8	5.5	5.0	4.3
	4	6.0	6.0	5.9	4.8	4.9	4.6
	5	6.3	5.9	6.0	5.9	4.5	4.5
	6	6.3	6.0	6.1	5.5	4.8	4.0
Mean/standard deviation for cherry processes		6.0 ± 0.34	6.0 ± 0.23	5.5 ± 0.55	5.5 ± 0.46	4.8 ± 0.29	4.1 ± 0.49
Acceptability (%)	1	88	88	50	63	75	13
	2	100	100	88	100	13	13
	3	100	100	50	88	38	25
	4	100	100	88	75	25	13
	5	100	88	88	75	25	25
	6	100	100	75	63	25	25
Mean/standard deviation for cherry processes		98 ± 0.04	97 ± 0.05	75 ± 0.20	78 ± 0.16	37 ± 0.23	20 ± 0.11

Table 15. Replicate averages, cherry process means, and standard deviations for shear press measurements of cherry pie filling.

Factor	Rep.	Processed cherries utilized in pie preparation					
		Frozen	IQF	Canned	Dried-coloring added	Dried-no coloring added	Dried-no SO_2 treatment
Shear press	1	2.76	2.68	0.94	2.22	1.82	2.22
	2	2.30	3.48	0.95	2.07	2.06	2.16
(lbs/gm)	3	2.59	2.96	0.96	2.38	1.96	2.12
	4	2.41	2.78	0.80	2.11	2.04	2.13
	5	2.00	3.44	0.97	2.18	2.17	2.21
	6	2.59	2.73	0.97	2.30	2.53	1.92
Mean/standard deviation for cherry processes		2.44 ± 0.27	3.01 ± 0.36	0.93 ± 0.07	2.21 ± 0.12	2.13 ± 0.24	2.10 ± 0.11
Shear press area-under-the-curve	1	2.62	2.37	1.13	2.15	1.91	1.78
	2	2.35	2.51	1.24	2.05	2.21	1.93
	3	2.45	2.13	1.20	2.08	1.86	1.79
	4	2.46	2.00	0.99	2.08	1.97	1.75
(cm^2)	5	1.99	2.43	1.16	1.94	2.04	1.88
	6	2.54	2.14	1.03	2.23	2.45	1.85
Mean/standard deviation for cherry processes		2.40 ± 0.22	2.26 ± 0.20	1.13 ± 0.10	2.09 ± 0.10	2.07 ± 0.22	1.83 ± 0.07

Table 16. Replicate averages, cherry process means, and standard deviations for Hunter colormeter measurement of color.

Factor	Rep.	Processed cherries utilized in pie preparation					
		Frozen	IQF	Canned	Dried-coloring added	Dried-no coloring added	Dried-no SO_2 treatment
Hunter L values	1	17.7	19.0	26.4	16.9	19.6	17.2
	2	16.4	19.0	24.1	16.7	20.8	16.3
(lightness)	3	16.9	19.4	24.2	15.7	19.0	16.1
	4	16.4	19.1	24.1	16.2	18.1	15.3
	5	16.1	19.0	22.4	16.7	18.7	16.9
	6	16.0	19.2	23.2	16.2	17.9	17.4
Mean/standard deviation for cherry processes		16.58 ± 0.63	19.12 ± 0.16	24.06 ± 1.34	16.40 ± 0.45	19.02 ± 1.07	16.53 ± 0.79
Hunter a_L values	1	20.4	23.6	21.0	20.7	16.7	12.6
	2	20.4	24.6	21.7	20.6	15.6	12.7
(redness)	3	21.4	25.3	21.8	19.5	18.0	13.5
	4	21.9	24.8	21.6	19.8	16.9	13.2
	5	20.1	24.3	20.7	20.9	17.0	13.8
	6	20.3	24.6	20.5	20.6	18.1	12.9
Mean/standard deviation for cherry processes		20.75 ± 0.72	24.53 ± 0.56	21.22 ± 0.56	20.35 ± 0.56	17.05 ± 0.92	13.12 ± 0.47
Hunter b_L values	1	9.4	10.8	14.0	9.7	10.4	8.5
	2	8.7	11.3	13.3	9.6	9.2	8.2
(yellowness)	3	9.6	12.0	13.2	9.0	10.7	8.6
	4	9.9	11.2	13.6	9.5	10.2	8.3
	5	8.9	11.3	12.3	9.9	10.2	9.4
	6	9.0	11.6	12.5	9.6	10.1	8.7
Mean/standard deviation for cherry processes		9.25 ± 0.46	11.37 ± 0.40	13.15 ± 0.65	9.55 ± 0.30	10.13 ± 0.50	8.62 ± 0.43

Table 17. Replicate averages, cherry process means, and standard deviations for sensory evaluation of frozen dried and nonfrozen dried cherry pie fillings.

Cherry attribute	Rep.	Dried nonfrozen	Dried frozen
Color	1	3.5	4.4
	2	4.0	4.1
	3	3.1	4.1
	4	3.0	3.9
	5	3.0	3.6
Mean/standard deviation for cherry processes		3.3 ± 0.43	4.0 ± 0.29
Appearance	1	3.5	3.9
	2	3.8	3.5
	3	3.4	3.9
	4	3.6	3.6
	5	3.1	3.6
Mean/standard deviation for cherry processes		3.5 ± 0.26	3.7 ± 0.19
Viscosity of sauce	1	5.8	6.0
	2	5.8	5.9
	3	5.5	5.8
	4	5.8	6.1
	5	6.0	5.6
Mean/standard deviation for cherry processes		5.8 ± 0.18	5.9 ± 0.19
Tenderness of cherry skin	1	6.3	5.4
	2	5.6	5.3
	3	5.3	5.1
	4	5.8	5.1
	5	4.3	4.6
Mean/standard deviation for cherry processes		5.5 ± 0.74	5.1 ± 0.31

Table 17. Continued.

Cherry attribute	Rep.	Dried nonfrozen	Dried frozen
Texture of cherry flesh	1	4.9	4.4
	2	4.8	4.3
	3	4.1	4.6
	4	4.8	4.3
	5	4.5	4.3
Mean/standard deviation for cherry processes		4.6 ± 0.33	4.4 ± 0.13
Flavor	1	4.3	5.6
	2	5.0	5.4
	3	4.9	5.5
	4	4.5	4.9
	5	4.8	5.4
Mean/standard deviation for cherry processes		4.7 ± 0.29	5.4 ± 0.27
Acceptability (%)	1	13	75
	2	38	50
	3	25	50
	4	25	75
	5	25	38
Mean/standard deviation for cherry processes		28 ± 0.11	60 ± 0.19

Table 18. Replicate averages, cherry process means, and standard deviations for shear press measurements and Hunter colormeter measurements of frozen dried and nonfrozen dried cherry pie fillings.

Cherry attribute	Rep.	Dried nonfrozen	Dried frozen
Shear press (lbs/gm)	1	2.06	1.97
	2	1.96	2.01
	3	2.04	2.09
	4	2.17	2.62
	5	2.53	2.80
Mean/standard deviation for cherry processes		2.15 ± 0.22	2.30 ± 0.38
Shear press area-under-the-curve (cm^2)	1	2.21	1.70
	2	1.86	1.80
	3	1.97	1.96
	4	2.04	2.02
	5	2.45	2.25
Mean/standard deviation for cherry processes		2.11 ± 0.23	1.95 ± 0.21
Hunter L values (lightness)	1	20.8	18.5
	2	19.0	17.9
	3	18.1	18.1
	4	18.7	17.8
	5	17.9	17.6
Mean/standard deviation for cherry processes		18.90± 1.15	17.98± 0.34

Table 18. Continued.

Cherry attribute	Rep.	Dried nonfrozen	Dried frozen
Hunter a_L values (redness)	1	15.6	16.9
	2	18.0	16.8
	3	16.9	17.7
	4	17.0	16.8
	5	18.1	16.5
Mean/standard deviation for cherry processes		17.12 ± 1.01	16.94 ± 0.45
Hunter b_L values (yellowness)	1	9.2	10.4
	2	10.7	9.9
	3	10.2	10.1
	4	10.2	10.0
	5	10.1	9.9
Mean/standard deviation for cherry processes		10.08 ± 0.54	10.06 ± 0.21

Table 19. Replicate averages for pH of cherry pie fillings.

Rep.	Processed cherries utilized in pie preparation						
	Frozen	IQF	Canned	Dried-coloring added	Dried-no coloring added	Dried-no SO_2 treatment	Dried frozen
1	3.1	3.3	3.2	3.3	3.2	3.1	3.0
2	3.4	3.3	3.2	3.4	3.2	3.3	3.0
3	3.3	3.1	3.2	3.2	3.4	3.3	3.2
4	3.3	3.2	3.2	3.2	3.3	3.3	3.2
5	3.2	3.1	3.2	3.2	3.2	3.4	3.0
6	3.2	3.3	3.2	3.2	3.2	3.5	3.0