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STUDIES ON FRUIT JUICES.

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INTRODUCTION.

The studies described in this bulletin were made with a view of finding methods for the preparation of juices from such fruits as the strawberry, blackberry, pineapple, orange, and lemon, which are less well known as sources of juice than the grape and apple. The work was directed toward the preparation of juices of well known varieties of fruit likely to be produced in quantities which would leave a surplus beyond the market demand for them as fresh fruit. The actual fruit used wherever practicable was that produced under typical conditions in localities where it is grown extensively. While final determination of the value of all the methods has not been made, the results of the studies are published in the belief that they will be useful to those giving attention to this neglected field of fruit conservation, and in the hope that they may stimulate others to develop methods which will make much fruit that is now wasted of commercial value to growers and a source of food to the people. The work was taken up at the suggestion of Mr. W. A. Taylor, of the Bureau of Plant Industry, and has been continued during the past four years in cooperation with him and with Mr. A. V. Stubenrauch, formerly of that bureau. The variety of fruit and the locality were selected by Mr. Taylor or Mr. Stubenrauch.

The experiments developed the fact that ordinary methods of sterilizing fruit juices by heat could be successfully applied to but a limited number of the special fruits such as the black raspberry, blackberry, black currant, sour cherry, and peach. In the case of the juices of the strawberry, red raspberry, red currant, pineapple, and the citrus fruits, as well as apple cider, sterilization by heat caused loss in flavor, and where kept after heat sterilization the juices of these fruits tended to lose color or flavor, or both. With these juices, then, the study was directed toward special methods of con-

This bulletin will be of interest only to those concerned with the commercial manufacture of fruit juices. The methods given call for cold storage, sterilization in carbon dioxid, and other processes not commonly available to the housewife.

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densing and keeping them by refrigeration or by the use of sterilization in carbon dioxid.

In this bulletin it is deemed best, therefore, to discuss first the general methods of extracting the juice and the ordinary forms of sterilization applicable to certain of these fruits, as a preliminary to the discussion of the special methods and their application to the juices of individual fruits.

GENERAL METHODS OF PREPARATION.

EXTRACTION OF JUICES.

Grinding.

If to be cold pressed, it is usually necessary to crush the fruit to facilitate the outflow of juice. Exceptions are the citrus fruits, which should be pressed after cutting in two, and pineapples, which may be pressed whole. Crushing is probably best effected by passing the fruits through an apple grater. The moving part of this machine, which is operated by power, consists of a rapidly rotating iron cylinder carrying short knives.

Heating.

To increase the juice yield, intensify the color, or impart the desired flavor to the juice, the fruit may be heated before pressing, in which case crushing may be omitted. Juices of the small fruits are successfully prepared with or without previous heating. Pineapples, peaches, and the citrus fruits should be cold pressed.

Heating is conveniently conducted in a steam-jacketed kettle made of copper with tin lining or in one of aluminum which should be fitted with a gate valve at the bottom for discharging the juice. To avoid scorching while heating, it is necessary to stir the fruit continuously.

Pressing.

The system of racks and cloths extensively employed in this country in the manufacture of grape juice and cider is probably also best for preparing the juices of other fruits. The fruit or fruit pulp is built up in the following manner, in the form of square masses called "cheeses," in heavy press cloths separated by racks. A square rack is placed on the press floor. On this is laid a square form, over which is spread the press cloth arranged diagonally, the corners lying on the sides of the form. The cloth is large enough to permit a depression to be made in the center and still inclose the pulp completely when the corners are folded over. In the depression is placed the ground fruit, which takes the shape of the interior of the form, thus making a square cake or "cheese." The corners of the cloth are folded over and, if necessary, pinned together. The form is then lifted off and another rack placed upon the cloth inclosing the "cheese." If desired another press cake may now be formed upon this rack, in which way a series of press cakes is built up until the

entire space between the press floor and the head of the press is filled.

Racks of hard maple are best, as this wood is very strong and quite flavorless. Extra heavy racks are required in pressing citrus fruits and pineapples. The press cloths should be of the extra-heavy quality, sold by manufacturers of cider and vinegar makers' supplies.

The rack-and-cloth method has the merit of affording an excellent opportunity for the drainage of the mass of fruit while under pressure. An additional advantage is the ease with which the press, racks, and cloths may be kept clean. After pressing it is usually necessary only to wash off the press bed and racks with a hose. When the pomace has been shaken out, the cloths are cleaned by hosing off and by an occasional washing. Racks and cloths must be kept dry when not in use. When operating continuously, racks and cloths are apt to become heavily charged with yeasts which infect the juices passing through and cause fermentation to occur very rapidly, in extreme cases even while pressing. This may be avoided by systematic daily cleansing of racks, cloths, and press.

The hydraulic type of press, operated by power, is very satisfactory. A steady but relatively light pressure is especially desirable in pressing the juice from the viscous masses formed by the ground pulp of peaches and of some of the small fruits.

REMOVAL OF SEDIMENT FROM FRUIT JUICES.

Newly expressed fruit juices are invariably turbid because of the suspended substances present. A convenient way for removing the greater part of the sediment consists in passing the juice through a milk separator, which causes a large portion of the sediment to adhere closely to the walls of the bowl. By filtering through paper pulp a perfectly clear juice may usually be obtained. Infusorial earth [1] is recommended by filter press manufacturers as an aid in the filtration of liquids which contain slime, and the experiments on fruit juices here considered indicate that this substance may be generally used in their filtration. The addition of 2 per cent or less of infusorial earth to a fruit juice will in many cases produce a perfectly clear filtrate, as the infusorial earth prevents the stopping up of the pores of the filter by the slimy suspended substances of the juice.

[1] Infusorial earth, also called diatomaceous earth, or kieselguhr, consists of nearly pure silica built up of the skeletons of microscopic sea animals called diatoms. When crushed and bolted it therefore exposes an enormous surface to liquids with which it is mixed. It possesses the property of opening up the slime which collects on the filter cloths, which otherwise would choke and render filtration impossible. Infusorial earth possesses this property to an extent not possessed by any other known substance. At the same time it is so inert that neutral or acid substances can be filtered through it practically without contamination. It is extensively mined in the United States and may be had finely bolted, ready for use in filtering, in carload lots at less than 2 cents a pound.

STERILIZATION OF FRUIT JUICES.

Containers of glass, porcelain, or tinned iron (tin cans) in which fruit juices may be sealed and sterilized are available. The juice may also be poured while very hot into sterilized wooden casks which are then sealed. Vessels of glass possess an obvious advantage in that a view of the contents may be had at any time without being opened.

Glass Containers.

CARBOYS.

The process of sterilizing the juice in glass carboys consists in filling previously warmed 5-gallon carboys with hot juice and sealing them while hot. They are warmed, either by placing them for a time in a closet heated by steam pipes, or by partly submerging and rotating them in a bath of hot water. The juice is conveniently heated in the steam-jacketed kettle already described (page 2) and then poured into the hot vessel, leaving space for the stopper, which is forced tightly into position.

Experience shows that the contents of partially filled carboys spoil more readily than those of full carboys, doubtless due to the fact that in the former the surface of the cork, which is further removed from the surface of the hot juice, does not receive the necessary heat treatment. When carboys of juice become infected, it is usually possible to trace the infection to the growth of organisms on the surface of the cork. It is, therefore, clear that the corks should be sterilized as completely as possible before use. Successful sterilization of the cork is somewhat difficult to accomplish. A satisfactory method consists in dipping the corks in melted paraffin, removing and then heating them in a steam closet for several days, during which time the paraffin is gradually absorbed. The corks should be steamed for a few moments or dipped in scalding water immediately before use.

After cooling, the carboys should be transferred to racks in a cool place where they can be inspected at frequent intervals. Such examination is imperative, as, in spite of the precautions described, a small portion of the juice usually shows evidence of infection, in the form of patches of mold floating on the surface. The flavor is often greatly injured and the juice rendered worthless by such infection. Before the colony of mold has become larger than a small dot floating on the surface, it should be removed and the juice sterilized. The advantage of the transparency possessed by glass containers is here evident. If development of yeasts, with the consequent bursting of carboys, occurs, serious defects in technique are probable, as yeasts in fruit juices are very easily killed by heating.

BOTTLES.

Flat-bottom bottles, ranging in capacity from 1 pint to 2 quarts, form the standard container in which fruit juices are at present offered for sale at retail. Together with the glass fruit jar so widely used in canning fruits in homes, they constitute the containers in which fruit juices are most easily sterilized on the small scale. The bottles may be filled with hot or cold juice as desired. If filled with cold juice, allowance must be made for expansion on heating and the bottles can not be filled as full as when warm juice is used. If filled with hot juice, they may be sterilized by being placed in a bath containing hot water and kept at the temperature desired. If filled with cold juice, it is necessary to place them in a bath filled at first with cold or lukewarm water, which is then rapidly heated to the temperature desired. Starting in this way and using a water bath heated by a steam coil, it is found that about half an hour is usually required for the contents of the bottles to reach the water bath temperature.

Bottles are easily sealed with corks, patent seals, or porcelain stoppers. Corks, which are best placed in position by means of a corking machine, must be given the treatment already described or one equally effective, before being used. They must be held securely in position during the heating. The method of binding a cloth firmly over the cork and tying it with a string is found to be much more easily applied than that of merely tying it with string or wire or using various types of cork holders. As patent bottle seals do not require tying during the heating, they are more convenient. Porcelain stoppers, once correctly fitted to the bottles, are very satisfactory in the preparation of fruit juices for home consumption, and by renewing the rubber washers may be used repeatedly. The bottles should be placed on their sides in the water bath, so that the inner surfaces of the corks receive the heat treatment while in contact with the juices. If this precaution is not taken, the chances of spoilage by mold growth are measurably increased.

On the whole, it is not improbable that fruit jars will prove more satisfactory as containers in sterilizing fruit juices on the domestic scale than bottles, because of the difficulties involved in using corks. Methods successfully employed in heating fruit in jars, or sealing it in jars while hot, work equally well for the corresponding fruit juices.

Wooden Containers.

Wooden casks are useful as containers in which fruit juices are to be kept for a limited time after sterilization. It is, however, difficult to sterilize the casks thoroughly before filling them with hot juice and to keep the juices in them sterile after they are filled and sealed. If large casks are used, the juice remains hot for a long time, thus

receiving a heat treatment much longer than necessary, which may injure the flavor. Another objection to casks is that the color and flavor of the juices are injured by the gradual solution of extract from the walls of the container. Wooden casks can not, therefore, be generally recommended as containers for fruit juices.

Tin Cans.

Juices may be far more easily sterilized in cans than in wooden casks. Cans, however, can not at the present time be generally recommended, as experiment shows that the tin is constantly dissolving in the juice, even when the type of can designated as "enamel lined" is used. There is consequent injury to color, in case of delicately tinted juices, and the flavor also is often injuriously affected. The ease with which juices are sealed and sterilized in tin cans, however, makes it seem probable that they may be successfully used in special instances for storage of sterilized juices, during limited periods at least.

Temperatures and Times of Heating.

In cooking the fruit pulp in the kettle the temperature does not exceed 95° C. (203° F.) during the time ordinarily required to reduce the fruit to a pulp, usually less than 5 minutes. In heating juice to be transferred to hot carboys the temperature should be carried up to from 85° to 90° C. (185° to 194° F.). The sterilizing temperatures here recommended for general use in preparing fruit juices are higher than those used in the earlier part of the experimental studies to be described later. In this work it was found that while at times complete sterilization was effected at a temperature of 70° C. (158° F.), or even lower, upon other occasions mold developed. Employment of higher temperatures resulted in almost wholly eliminating the difficulties of mold growth in juices heated in bottles.

A temperature of at least 80° C. (176° F.) is recommended for all fruit juices sterilized in bottles, allowing, when starting with cold juice, half an hour for the juices to attain bath temperature, and keeping the bottles at this point for at least half an hour. Where it is found that no injury to flavor results, this temperature may be increased with advantage. Usually merely filling the bottles or fruit jars with the boiling-hot juice and sealing them immediately is satisfactory. An exception, however, to this treatment is found in the case of lemon juice, the flavor of which is much injured by heating to 80° C. This juice is easily sterilized, without serious injury to the flavor, by being heated to 70° C. for half an hour, allowing half an hour for the juice to attain bath temperature.

With juices sterilized in carboys the situation is less satisfactory, as infection with molds often occurs when all of the precautions already described have been taken. The method of sterilizing

juices in carboys, therefore, requires further study. It is not improbable that a method of sealing in which no air space remains in the carboy, or in which no oxygen is present in the gases above the juice surface, would result in the complete arrest of the development of molds.

SPECIAL METHODS OF PREPARATION.

As has been stated, the methods of handling just described can be successfully applied to but a limited number of those juices tried, namely, black raspberry, blackberry, black currant, sour cherry, and peach. In the case of strawberry, apple, and other juices which are greatly injured in distinctive flavor by being heated, it is possible to retain the flavor satisfactorily by keeping the juice in freezing storage at a temperature of 14° F. Although certain juices, as pineapple and orange, are not greatly injured in flavor by sterilization, they change in flavor and color upon being kept at ordinary temperatures after sterilization. Keeping such juices in cold storage at from 32° to 36° F. causes satisfactory retention of the color and flavor. Another cold-storage method of general application to fruit juices, and one particularly valuable for fruit juices the distinctive characters of which are injured by heat, is the method of concentrating by freezing.

Juices of oranges, lemons, and pineapples darken greatly in color if sterilized and subsequently kept in contact with atmospheric oxygen. Satisfactory color retention can here be had by sterilizing and keeping the juices free from atmospheric oxygen, which is most conveniently effected by carbonating slightly and sterilizing them in carbon dioxid.

APPLICATION OF COLD STORAGE TO FRUIT JUICES.

Storage of Raw Juices at 32° to 35° F.

Apple juice, cooled quickly after pressing to 32° F., and stored at this temperature, will keep for from 6 weeks to 3 months before it ferments sufficiently to be considered hard or sour.[1] Unpublished experiments on the keeping of raw orange juice at from 32° to 35° F. show that its flavor deteriorates quite rapidly. An unfavorable feature of storage of raw fruit juices at from 32° to 35° F. is the development of molds at juice surfaces. It is not improbable that simple measures for the suppression of the mold growths could be successfully used, as, for example, keeping the containers entirely filled, or keeping the juice surfaces well blanketed with a layer of carbon dioxid, or possibly using ultraviolet light. It seems probable, however, that cold storage of freshly expressed juices at from 32° to 35° F. is of but limited application, as the activities of microorganisms are not sufficiently held in check.

[1] U. S. Dept. Agri., Bureau of Chemistry Cir. 48.

Cold Storage of Sterilized Juices at 32° to 35° F.

Experiments which consisted simply of keeping bottled sterilized juices at from 32° to 35° F. indicate that certain fruit juices, notably orange, pineapple, and currant, retain their color and flavor far better at low temperatures than at the temperatures of ordinary storage.

Freezing Storage of Raw Juices.

Juices may be kept in freezing storage at temperatures approximating −10° C. (14° F.) for many months without marked change in composition or flavor or development of microorganisms.

CONCENTRATION BY FREEZING.

Upon freezing a fruit juice, ice separates, the juice becoming correspondingly concentrated. As the temperature falls lower and lower, more and more ice forms, and the nonfrozen liquid becomes more and more concentrated, until finally a solid block of frozen fruit juice, consisting of ice and concentrated, sirupy liquid, results. If the block of frozen fruit juice is now coarsely broken up and centrifugalized, the sirup can be removed from the ice, and the latter discarded. A concentrated fruit juice possessing the color and flavor of the original fruit is thus obtained.

In freezing the juices are placed in containers having slightly flaring sides, so that by warming the sides and bottom the block of frozen juice may be easily removed. Slow freezing is more satisfactory than rapid freezing in an ice-cream freezer, as in the former instance the crystals of ice formed are large, consisting toward the end of the freezing of long, thin plates reaching in toward the center of the container, while in the ice-cream freezer the ice forms a finely felted mass from which the concentrated juice is separated with difficulty. On the laboratory scale the crushing and centrifugalizing is best carried on in a cool room, thus avoiding undue melting. On a commercial scale this precaution is not so necessary. Temperatures approximating −10° C. (14° F.) are sufficiently low to give to concentrated juices a solids content of about 50 per cent. Such juices ferment very slowly at room temperatures, the presence of sugar and acid retarding greatly the growth of microorganisms.

The method may be easily extended to commercial proportions, as ice crushers and centrifugals, readily obtainable in the market, can be used without modification.

STERILIZATION IN CARBON DIOXID.

In Carboys.

The carboys are filled nearly full with the cold juice to be sterilized and placed in a bath of cool water. The bath temperature is rapidly brought up to the point at which it is desired to sterilize the product, while a stream of carbon dioxid is slowly passed into each carboy

through a glass or block tin delivery tube reaching nearly to the bottom. When the desired temperature has been reached, the flow of carbon dioxid is momentarily increased, the delivery tube being withdrawn at the same time and a paraffined cork stopper, taken from scalding water, instantly inserted.

In Bottles.

The juice is cooled to refrigerator temperatures in a cask and a current of carbon dioxid passed through until the product tastes distinctly of the dissolved gas. It is then transferred to the bottles. The air above the surface of the juices in the bottles is displaced by a rapid current of carbon dioxid after which the cork is instantly forced into position, tied in place and the bottles and contents given the necessary heat treatment. By thus lightly carbonating, excessive pressures due to carbon dioxid are not developed on heating.

The principal effect of thus excluding atmospheric oxygen by carbon dioxid is the satisfactory retention in color observed in citrus and pineapple juices. The products are at the same time improved in palatability by the presence of carbon dioxid.

EXPERIMENTAL WORK.

A condensed summary of the experimental work with the different fruit juices taken from the laboratory notes follows. Except where noted to the contrary, the conclusions are based on the work of three or more successive seasons.

STRAWBERRY JUICE.

Locally-grown berries, variety Gandy, were used in most instances.

Pressing.—To secure good yields it was necessary to grind before pressing, the pressure being applied very gradually to allow time for drainage. The yields ranged from 63 to 88.06 per cent.

Sterilization.—The juices were sterilized without injury to color, but with marked injury to fresh fruit flavor. A cooked strawberry taste developed.

Keeping after sterilization.—Color and flavor changed greatly on keeping the juice in common storage, even in carbon dioxid. The beautiful, bright, red colors faded to dull brownish-red tones, and all distinctive flavor of strawberry disappeared, except for a slight cooked strawberry aroma. Disagreeable flavors developed upon prolonged storage at common temperatures.

Keeping in freezing storage and concentration by freezing.—Raw strawberry juice retained well its original color and flavor in freezing storage at $-10°$ C. (14° F.) for nearly 8 months. The juice could be concentrated easily by freezing, but when partly concentrated became gelatinous, the juice and ice separating with difficulty.

Discussion.—The preparation of strawberry juice by sterilization methods can not be advised because the distinctive flavor of fresh strawberries is greatly injured by sterilization. During the period of keeping it at ordinary temperatures after sterilization, further deterioration in flavor, accompanied by fading of color, occurs.

RED CURRANT JUICE.

Red currants grown in New York State, mostly of the Fay variety, were used.

Pressing.—Yields varying from 65.5 to 72.8 per cent were obtained by passing currants through the apple grater and pressing them without previous heating. Yields from 73.2 to 81.3 per cent were obtained by cooking before pressing.

Sterilization.—Upon heating, slight but distinct loss in fruitiness occurred. The color was unchanged.

Keeping after sterilization.—On keeping in storage at room temperatures after sterilizing them, the juices very gradually lost in distinctive flavor as well as in color. The sterilized juices kept in cold storage, at from 32° to 35° F., retained their color and flavor very well.

Storage of raw juices at freezing temperatures and concentration by freezing.—The color and flavor of raw currant juices kept in freezing storage at 14° F. were well retained. Juice concentrated by freezing formed an intensely acid liquid, keeping well the color and flavor of the original juice.

Jelly making from sterilized juices.—Well-flavored jellies, possessing clean, sharp, acid tastes, were invariably obtained. The jellies prepared from the sterilized juices kept in cold storage were much more brilliantly colored than those from the same juices kept in common storage. Jellies prepared from cold-pressed juices were less firm than those made from the hot-pressed juices. The latter, however, were not stiff enough to hold their shape well.

Discussion.—Juice from red currants is best prepared by cooking until soft and pressing. The juices are then freed from sediment and sterilized in glass. For the preservation of color it is necessary to keep them at low temperatures. Temperatures of from 32° to 35° F. are satisfactory. Red currant juices are much too acid for use as beverages without dilution and sweetening, in this respect resembling strawberry juice, though more acid. The freezing storage methods work well, but are hardly necessary, as color and flavor are well retained during sterilization.

BLACK CURRANT JUICE.

Black currants, variety not determined, grown near Geneva, N. Y., were used.

Pressing.—It was necessary to heat the fruit before pressing to secure a satisfactory yield and quality of juice. The yields of hot pressed juice ranged between 68.4 and 78.1 per cent.

Sterilization and keeping after sterilization.—The characteristic color and flavor were well retained in juices sterilized and kept after sterilization at ordinary temperatures, even for periods as long as several years.

Application of special methods.—Keeping the juice after sterilization at low temperatures or in carbon dioxid did not result in a product perceptibly better in quality than did keeping it under usual conditions where, as stated before, the distinctive qualities were excellently well retained. Upon concentration by freezing, a very viscid highly acid concentrate was obtained.

Jelly making from sterilized juice.—Excellent jellies were easily prepared from sterilized black currant juice by adding an equal weight of sugar and cooking.

Discussion.—Juice of black currants may be prepared readily by cooking, pressing, and sterilizing in sealed containers. It is practically unaffected in color and flavor by sterilization, and the color and flavor are well retained. Application of special methods to secure the retention of color and flavor is therefore unnecessary.

BLACKBERRY JUICE.

The data are based on results obtained with wild blackberries and with the following cultivated varieties: Eldorado, Early Harvest, and Erie.

Pressing.—Cooking before pressing increased the yield and gave juices possessing the desirable aroma and flavor of cooked blackberries. It was necessary to apply the pressure very gradually to avoid pressing the pulp through the press cloths. Yields when cold pressed ranged from 66.9 to 69.6 per cent; hot pressed, from 74.4 to 80. 9 per cent.

Sterilization.—The juices lost but little in flavor and color on being sterilized.

Keeping after sterilization.—Upon being kept at ordinary temperatures after sterilization the distinctive blackberry color and flavor were well retained for a period of at least 6 months. On keeping for longer periods the flavor gradually lost its blackberry character, and the color slowly faded. Juice kept at from 32° to 35° F. and in carbon dioxid after sterilization was not perceptibly superior in distinctive flavor and color to that kept at ordinary temperatures in air.

Concentration by freezing.—The juice was easily concentrated by freezing.

Discussion.—A satisfactory method of preparing the juice of wild or cultivated blackberries based on the foregoing results consists in cooking the berries, pressing them, freeing the juice from sediment and sterilizing it in bottles. Though quite acid, juices of both wild and cultivated varieties are attractive when so prepared.

BLACK RASPBERRY JUICE.

Locally-grown berries of the Doolittle and Kansas varieties were used.

Pressing.—Upon being pressed without previous heating, yields of from 61.8 to 75 per cent of juice were obtained. Yields as high as 76.18 per cent were secured by hot pressing. Pressure must be applied very gradually for satisfactory yields.

Sterilization.—The juices were not injured perceptibly in flavor or in color by sterilization.

Keeping after sterilization.—Juices prepared by either hot or cold pressing retained their color and flavor, which were practically unchanged for prolonged periods at common temperatures. Special measures, such as keeping at low temperatures or sterilizing in carbon dioxid, are therefore not necessary.

Concentration by freezing.—Upon concentrating black raspberry juice by freezing, a peculiar coagulum formed, consisting apparently of flocculated coloring matter. Concentrating by freezing as applied to black raspberries did not appear to be of particular value, in view of the excellent color and flavor retention of the juice when sterilized and kept at room temperature.

Discussion.—Juices can thus easily be prepared from black raspberries by crushing and then pressing them with or without previous heating. The characteristic color and flavor of black raspberry juice are excellently well retained upon sterilizing it and keeping it after sterilization at ordinary temperatures for prolonged intervals, even as long as several years. The sterilized juice is rather acid, requiring the addition of sugar to make it palatable.

RED RASPBERRY JUICE.

Locally-grown berries of the Miller, Brandywine, and Cuthbert varieties were used.

Pressing.—High yields of juice, ranging from 71.9 to 82.3 per cent, were easily obtained by crushing and pressing the berries. It was necessary to press slowly and to use double press cloths.

Sterilization.—Although red raspberry juices underwent a distinct change in flavor on heating, the palatability of the juice was not greatly injured.

Keeping after sterilization.—The color faded and disappeared and the flavor changed greatly, even during storage periods of 6 months. Bottling the juice in carbon dioxid and keeping it in cold storage at from 32° to 35° F. after sterilization had no apparent effect in retarding these changes in color and flavor.

Keeping raw juice in freezing storage.—The color and flavor were excellently well retained.

Concentration by freezing.—The color and flavor were well retained. Highly colored, richly flavored, very acid juices were obtained.

Discussion.—The color and flavor, while thus found to be injured but slightly by sterilization, deteriorate greatly on keeping, even though carbonated and kept in cold storage. Only in freezing storage are the color and flavor satisfactorily retained. It is, however, possible to keep red raspberry juice by freezing storage methods.

PINEAPPLE JUICE.

Florida-grown red Spanish pineapples were used in all cases.

Pressing.—High yields of juice were invariably obtained. Juice derived from the peels possessed rather disagreeable soapy flavors. Fresh pineapple juice prepared from crushed unpeeled pineapples was, therefore, less attractive than that from pineapples which were peeled before being pressed. It was found, however, that pineapples which had not been peeled or previously crushed, but the crowns of which had been removed, might be placed on their sides in cloths on extra heavy racks and pressed. So prepared, the juice was not perceptibly injured by off flavors derived from the peel.

Effect of heating on flavor.—Although heating the juice caused slight but definite changes in flavor, it did not markedly injure the juice.

Effect of storage on color and flavor.—Gradual darkening occurred where precautions were not taken to exclude atmospheric oxygen in bottling. This color change was controlled by bottling the juice in carbon dioxid. In addition to this, carbon dioxid imparted an agreeable flavor to the juice, simulating the freshness of the original fruit. When stored at common temperatures, the gradual development of a peculiar taste, designated as a stale flavor, occurred, and much of the rich flavor of the original juice disappeared. The characteristic flavor, however, was sufficiently well retained for recognition of the juice as pineapple. Cold storage at from 32° to 35° F. prevented perceptible losses in flavor during a period of 7½ months.

Storage at freezing temperatures.—During storage at freezing temperatures, −10° C. (14° F.), the color and flavor were well retained.

Special methods.—A voluminous precipitate formed on heating pineapple juice. A treatment consisting of warming the juice to 85° C. and allowing it to stand for one hour was sufficient to completely precipitate the heat-coagulable substances. The bulk of the coagulum was removed by passing the cooled juice through the milk separator. Filtration through paper pulp was thus greatly facilitated, as clogging of the filter was retarded by the removal of the coagulum.

Discussion.—It is necessary to take special precautions in the preparation and storage of pineapple juice to prevent deterioration in distinctive color and flavor. Sterilization and the subsequent keeping of the juice free from contact with atmospheric oxygen result

in satisfactory color retention. Keeping it in cold storage at from 32° to 35° F. after sterilization causes a satisfactory retention of distinctive pineapple flavor. A heat treatment, consisting in heating to about 85° C. for an hour, is sufficient to precipitate the coagulable matter. This should be followed by prompt cooling. Removal of most of the suspended matter by use of the milk separator facilitates subsequent filtration. A perfectly brilliant juice of very attractive pineapple flavor is then easily obtained by filtering, carbonating lightly, and finally sterilizing.

CHERRY JUICE.

The English Morello variety grown near Geneva, N. Y., was used in all cases.

Pressing.—High yields of juice, ranging from 73.4 to 80.4 per cent, were easily obtained by pressing the crushed cherries without previous heating.

Sterilization and keeping after sterilization.—The distinctive color and flavor were well retained when heated in carboys, racked into bottles, resterilized, and afterwards kept at room temperatures.

Discussion.—Juice from English Morello cherries can thus be successfully prepared by the usual methods. Juice prepared from cherries crushed, kernels and all, before pressing, was slightly better than juice prepared without crushing the kernels, because it possessed flavors derived from the kernels.

PEACH JUICE.

Georgia-grown peaches were used in all cases. The varieties were Carman, Hiley, and Elberta.

Pressing.—Juices were prepared readily by crushing and pressing the fruit. They were quite viscous, and long, slow pressings were necessary. If the kernels were crushed before pressing a marked pit flavor appeared in the juice.

Sterilization and keeping after sterilization.—The prepared juices lacked somewhat in distinctive peach flavor, but no evidence of deterioration of flavor on sterilization or keeping after sterilization was found.

Filtering.—The addition of less than 1 per cent of infusorial earth to peach juice rendered it readily filterable.

Discussion.—Upon the whole, peaches are somewhat less promising as a source of juice than many other kinds of fruit. Juices of tree-ripened peaches should, however, be tried before final conclusions are drawn.

HUCKLEBERRY JUICE.

The species *Gaylussacia baccata* was used. One season's work only was carried on.

Huckleberries yielded their juice readily when pressed either with or without previous heating. Juice prepared from berries not heated

before pressing lacked in distinctive flavor; that from cooked fruit possessed a distinctive aroma which was not well retained on keeping. It was intensely colored. Upon the whole, huckleberries are not of promise as a source of juice.

LEMON JUICE.

California-grown lemons were used in all of the studies.

Pressing.—The juice was prepared readily by cutting each lemon transversely into two or more pieces, placing the fruit in cloths between racks and pressing it. Extra heavy or double racks are required. Good yields of juice, ranging from 35 to 40 per cent by weight of the lemons, were obtained.

Removal of sediment.—A large proportion of oil was removed from the skins in pressing. This was removed by passing the juice through a milk separator, which at the same time removed a portion of the matter suspended in the juice. Finally, the juice was rendered almost clear by filtering it through paper pulp. Infusorial earth can be successfully used in preparing clear juices.

Sterilization and keeping after sterilization.—The juice was sterilized without marked loss in flavor by heating it to 70° C. for half an hour. When kept at low temperatures it retained well a rich lemon flavor for many weeks. Sooner or later, however, a peculiar flavor, designated as the "bottled lime-juice" flavor, made its appearance, the typical lemon flavor at the same time becoming less conspicuous. Simultaneously, darkening in color occurred unless special measures were taken to protect the lemon juice from contact with the air. By bottling in carbon dioxid before sterilizing the juice, satisfactory color retention was secured. Oxygen may also be successfully kept from contact with the juice by sealing the containers in vacuum. The exclusion of air, however, had no perceptible effect on the retention of flavor. So far as tried, keeping the juice in cold storage, at from 32° to 35° F., was not successful in controlling the flavor change.

Concentration of lemon juice by freezing.—Lemon juice is readily concentrated by freezing. As lemon juice is easily sterilized without marked injury to flavor, however, it is anticipated that the method of concentrating by freezing will be of little value here.

Discussion.—Up to the present time the department is not in a position to suggest a satisfactory method for the preparation of lemon juice, as none has been found for properly retaining the characteristic lemon flavor during keeping at ordinary temperatures.

Flavor is quite well retained, however, for at least several weeks. Other features of the problem of preparing lemon juice have been mastered. Satisfactory yields of juice are invariably obtained by cutting and pressing. Color retention is assured if the juice is lightly carbonated, and boiled and sterilized in carbon dioxid.

The milk separator can be used in removing oil and the bulk of the suspended matter. Preliminary experiments show that the addition of infusorial earth to the juice will make possible the preparation of a brilliant juice entirely free from suspended matter or sediment.

ORANGE JUICE.

Florida- and California-grown oranges were used.

Pressing.—Pressing was successfully accomplished by cutting each orange transversely into two or more pieces, forming the cut fruit into "cheeses" (p. 2) in cloths and then pressing it. Extra heavy or double racks were required. Removing the peels before pressing was found inadvisable, as juices so prepared were deficient in orange flavor, and cooked tastes, developed during sterilization, were more prominent than in juices prepared from unpeeled fruit. In a typical experiment with Florida oranges the yield of juice was 52.7 per cent.

Sterilization and keeping after sterilization.—The juice underwent a slight but distinct change in flavor on being sterilized at 80° C. When afterwards kept at temperatures of from 32° to 35° F., no further flavor change occurred for many months. When kept at ordinary temperatures, however, marked flavor deterioration occurred. The flavor changes were accompanied by darkening of color, which, however, could be controlled by carbonating the juice and sterilizing it in carbon dioxid. The suggestion of excluding the air from contact with the surface of orange juice to control color change is due to R. F. Bacon, formerly of the Bureau of Chemistry. It has been tried with other fruit juices, and, as already described (p. 7), found useful in the case of lemon and pineapple juices. Carbonating or keeping in carbon dioxid had no effect on the retention of the distinctive flavor of orange juice.

Removal of sediment from orange juice.—Freshly expressed orange juice contained much suspended matter which detracted from the appearance of the sterilized juice. Experiments consisting in passing the juice through the rotating bowl of a milk separator showed that a large part of the suspended matter can be easily removed. A small portion of the juice carrying the orange oil passed from the separator through the cream screw. A certain amount of this juice, added to the main body of juice which has passed from the milk separator through the milk screw, restored the flavor of orange oil to the juice to the degree desired. Infusorial earth added to orange juice promotes filtration.

Freezing and thawing orange juice.—Upon freezing orange juice and allowing it to thaw, more or less complete coagulation of suspended matters occurred. This fact is possibly of importance in the development of the technique of preparing a clear orange juice of satisfactory flavor.

Concentration by freezing.—Concentration to a sirup was easily accomplished.

Discussion.—The studies on orange juice have not led to results on which a method for its preparation may be based, as no way to successfully retain fresh orange juice flavor has been found. Sterilizing the juice injures the flavor, which continues to deteriorate gradually when the juice is kept at ordinary temperatures. In cold storage, however, the flavor is well retained. Certain features of the technology of preparing orange juice have been mastered. Thus, the milk separator may be successfully employed in removing excessive amounts of oil as well as suspended matters from freshly expressed juice. Carbonating and sterilizing the juice in carbon dioxid, as well as cold storage at from 32° to 35° F., permit of satisfactory color retention. Concentration by freezing to a sirup is of promise, but this subject, as well as the use of infusorial earth in filtering, remains to be further worked out experimentally.

SUMMARY.

Pressing.

Satisfactory yields of juice were easily obtained from all of the fruits studied. Lemon and orange juices were best expressed by cutting each fruit into several pieces and then pressing, a method which could be successfully used in pressing pineapples, although the method of pressing the fruit without previous cutting is probably superior. It was found advisable to pass all of the other kinds of fruit pressed without heating through an apple grater to facilitate the outflow of the juice.

Heating before pressing in the case of black raspberry, blackberry, red currant, black currant, and huckleberry juices resulted in larger yields of juice and the development of more color and a more distinctive flavor than were obtained from cold pressing. Strawberries, red raspberries, cherries, peaches, pineapples, lemons, and oranges were cold pressed.

Effect of Heating on Distinctive Colors and Flavors.

Heating the juices sufficiently to sterilize them did not affect injuriously the color of any of the fruit juices, though pineapple, lemon, and orange juices usually darkened somewhat if heated in the presence of dissolved oxygen or if exposed to atmospheric oxygen during the heat treatment.

The distinctive flavor of the fresh fruit was greatly injured and the familiar cooked strawberry taste appeared when strawberry juice was sterilized by heat. The fresh fruit flavor of orange juice was also distinctly injured when the juice was heated. Although all lost in the quality of freshness, heating did not seriously affect the flavor

of other fruit juices, except in cases where the heat employed was excessive.

Retention of Distinctive Colors and Flavors.

The extent to which color and flavor were retained on keeping the juice after sterilization varied greatly in the juices from the various fruits.

In strawberry juice the brilliant red color of the freshly sterilized juices in all cases faded greatly and further flavor losses occurred. Sterilization and subsequent keeping in carbon dioxid were not effective in securing color retention.

Red currant juice very gradually lost in distinctive color and flavor on being kept at room temperatures after sterilization and keeping in carbon dioxid was not effective in securing either color or flavor retention. Cold storage at from 32° to 35° F. was found to be a very satisfactory means of controlling color and flavor changes.

The distinctive colors and flavors of black currant, blackberry, and black raspberry juices were satisfactorily retained during prolonged periods at common storage. The flavor of blackberries was, however, distinctly less well retained than that of black currants or black raspberries, though it did not undergo a perceptible change during a storage period of six months.

In the case of red raspberries the distinctive color and flavor were poorly retained, even on keeping the juice in carbon dioxid in cold storage at from 32° to 35° F.

When sterilized and subsequently kept in carbon dioxid the distinctive color of pineapple juice remained practically unchanged. When exposed to atmospheric oxygen at juice surfaces during and after sterilization, marked darkening occurred. Change in color was also found to be greatly, though not wholly, retarded by keeping the juice in cold storage at from 32° to 35° F. On keeping the juice at ordinary temperatures the distinctive pineapple flavor gradually lessened, though the juices remained recognizable as pineapple. By keeping in cold storage at from 32° to 35° F. flavor change was almost wholly prevented.

The distinctive colors and flavors of peach and cherry juices were quite well retained while kept at room temperatures. Huckleberry juice, hot pressed, lost in flavor on keeping.

Lemon juice darkened in color if sterilized and kept in the presence of atmospheric oxygen, though the color was satisfactorily retained when the juice was sterilized and kept in carbon dioxid or in vacuum. In all cases an off-flavor, designated as a "bottled lime-juice" flavor, appeared in the lemon juice after it had been kept for a time after sterilization, even though in cold storage at from 32° to 35° F.

Orange juice also underwent a marked darkening in color when kept at room temperatures after being sterilized. The color was fairly well retained when atmospheric oxygen was excluded by sterilizing the juice and subsequently keeping it in vacuum or in carbon dioxid, and the change in color was well controlled by keeping the juice at low temperatures. The flavor of sterilized orange juice, already slightly injured by the heating necessary for sterilization, underwent further changes when kept at room temperatures. It was found that by keeping the juice in cold storage at from 32° to 35° F. the flavor was well retained for long periods.

Keeping in Freezing Storage and Concentration by Freezing.

The distinctive colors and flavors of all fruit juices kept in freezing storage at about −10° C. (14° F.) were found to remain practically unchanged during many months, except that a peculiar coagulation of much of the coloring matter appeared in the juice of the black raspberry. It was possible to concentrate fruit juices to sirups by freezing out the water as ice and centrifugalizing. Characteristic colors and flavors were well retained on concentrating.

Filtering.

Infusorial earth greatly promotes the filtering of fruit juices, as it retards greatly the clogging of the filter.

CONCLUSION.

Juices of red and black currants, blackberries, black raspberries, sour cherries, and peaches may easily be successfully prepared on the large scale by the methods used for the preparation of grape juice, as they retain their characteristic properties well on being sterilized and stored away. Strawberry juice and red raspberry juice are not suited for preparation on the large scale because of the readiness with which the distinctive colors and flavors change. Huckleberry juice is somewhat characterless. Pineapple juice requires special methods for its successful preparation not necessary in case of the other juices. Its preparation on the commercial scale, however, is of marked promise.

Satisfactory methods for the preparation of lemon and orange juices have not been developed. The peculiar change in flavor of lemon juice stored after sterilization, even at low temperatures, is an obstacle to be overcome before the preparation of the juice on the large scale can be considered advisable. The problem of preparing orange juice is not without promise. It is not unlikely that highly specialized methods in which cold storage will play a prominent, if not dominating, part will be required.

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