poses of human nutrition a high copper content in the pulp is important; for purposes of stock feeding the mineral content of the peel is significant; for purposes of germination the mineral content of the seed merits attention.

In the second place, the mineral content of citrus fruits is a somewhat unsatisfactory term, because of the apparent variability in the content of these elements; the copper content of citrus fruits, for example, seems to depend upon the care and treatment of the tree to a vastly greater extent than does the pH sugar or acid content. Accordingly, to establish any sort of average value for mineral content, fruit of several seasons must be considered. This data is not yet available.

We can, however, say that by spectrographic methods we find in the citrus fruit copper, zinc, manganese, aluminum, nickel, cadmium, lead, in addition to the well known calcium, magnesium, etc. These elements occur in varying amounts in the different parts of the fruit, and apparently depend a great deal on the care of the tree. The relation of the less common elements to plant nutrition, the relation of care and treatment of the tree to the production of a citrus fruit ranking high in minerals are important in plant nutrition. Similar problems for crops other than citrus are all receiving attention by the Florida Agricultural Experiment Station.

POSSIBILITIES OF PREPARING ALCOHOLIC CITRUS BEVERAGES*

Harry W. von Loesecke
U. S. Citrus Products Station, Food Research Division
Bureau of Chemistry and Soils, Winter Haven, Florida

Note: The data given in the following paper are merely experimental and are not to be taken as the basis for the establishment of a winery or a distillery of alcoholic citrus beverages. Not only is it illegal at the time of writing this paper to manufacture distilled beverages in the State of Florida, but there are also certain aspects of the internal revenue laws prohibiting the fortification of any kind of wine except sweet wine made from the juice of grapes and also prohibiting the use of sugar in the manufacture of fruit brandies. There are also regulations of the Alcohol Tax Unit, Internal Revenue Service, (2) “wine is the product made by the normal alcoholic fermentation of the juice of sound ripe grapes ** *” In view of this definition it would seem that fermented citrus juices could not be called wine. It is permissible, however, at the present time to designate the product obtained by fermenting citrus juices, as wine with proper qualification as to fruit of origin and such wines are taxed according to their alcoholic content in the same manner as wine from grapes.

Although before prohibition citrus wines were prepared on a commercial scale, largely in California, the literature contains little of practical
value. McNair (3) gives a few analyses of citrus wines which he found, in general, to be of very poor quality.

Probably the reason wine was not first prepared from citrus was that in ancient times pure sugar was too scarce to be used as a source of alcohol and hence a fruit had to be selected which by itself contained sufficient sugar to yield upon fermentation enough alcohol to produce a wine of good keeping quality. Sound wines cannot be obtained from citrus juices unless sugar is added to the juice before fermentation. If no sugar is added, the wine will contain only about four per cent. alcohol, rendering it unpalatable and of poor keeping quality.

The composition of grape juice as compared with orange and grapefruit juices is shown in Table I.

EXPERIMENTAL

Citrus wines cannot be prepared in the same manner as wine from grapes. In a majority of cases grape wine is made by crushing the grapes and then allowing the mass to ferment spontaneously. If citrus wines are prepared in this manner a uniform product would be difficult, if not impossible, to obtain. In some instances water is added to the crushed grapes to reduce the acidity to about 0.5 per cent. or sugar introduced to compensate for the deficiency of sugar in certain varieties of grapes. The Creole citrus wine produced in Louisiana is made by diluting the juice with water, adding sugar and then allowing the mass to ferment. The aroma of citrus juices is so elusive that any dilution with water greatly diminishes the bouquet of the wine. Furthermore, citrus wines lack body unless excessive amounts of sugar are added. The addition of water to the juice before fermentation will tend to make the wine more watery.

PREPARATION OF WINES

In our experiments pure cultures of wine yeasts were used. We have studied four thus far: Saccharomyces ellipsoideus, 1; Hansen; Saccharomyces ellipsoideus, var. Champagne; Saccharomyces ellipsoideus Burgundy, and Saccharomyces spiritus vini. The Champagne yeast is said to develop as much as 16 per cent. alcohol by volume and we have obtained as high as 17 per cent. alcohol by volume, but this is an exception.

The volume per cent. of alcohol obtained from grapefruit juice of varying Brix (total Soluble Solids) and using three different types of yeast is

---

TABLE I

<table>
<thead>
<tr>
<th>Composition of Grape Juice, Orange Juice and Grapefruit Juice*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>Grape Juice, American, Average of all types</td>
</tr>
<tr>
<td>Grape Juice, European, Average of all types</td>
</tr>
<tr>
<td>Orange Juice, California grown fruit</td>
</tr>
<tr>
<td>Orange Juice, Florida grown fruit</td>
</tr>
<tr>
<td>Grapefruit Juice, Florida grown fruit</td>
</tr>
<tr>
<td>Grapefruit Juice, California grown fruit</td>
</tr>
<tr>
<td>Grapefruit Juice, Arizona grown fruit</td>
</tr>
</tbody>
</table>

TABLE II
PER CENT. ALCOHOL BY VOLUME OBTAINED FROM GRAPEFRUIT JUICE OF VARYING BRIX
(Temperature of fermentation: 28° C)

<table>
<thead>
<tr>
<th>Brix (Total Soluble Solids)</th>
<th>16.4</th>
<th>23.5</th>
<th>26.6</th>
<th>29.2</th>
<th>34.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alcohol Per Cent. by Volume</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>S. Ellipsoides var. Champagne</td>
<td>8.6</td>
<td>12.6</td>
<td>14.7</td>
<td>15.1</td>
<td>14.8</td>
</tr>
<tr>
<td>S. Ellipsoides Burgundy Yeast</td>
<td>8.3</td>
<td>13.4</td>
<td>15.3</td>
<td>16.4</td>
<td></td>
</tr>
<tr>
<td>S. Ellipsoides Hansen</td>
<td>8.5</td>
<td>13.5</td>
<td>14.2</td>
<td>13.5</td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td>8.5</td>
<td>13.3</td>
<td>14.7</td>
<td>15.0</td>
<td></td>
</tr>
</tbody>
</table>

shown in Table II. Cane sugar was added to increase the Brix.

It will be noticed from Table II the per cent. by volume of alcohol in the finished wine very nearly approaches one-half of the Brix of the juice before fermentation.

The data also indicate that the optimum Brix should be about 26° to obtain a wine containing the highest amount of alcohol. However, a wine containing 13 per cent. alcohol by volume should possess good keeping qualities and the tax would be less than one containing 15 per cent. alcohol by volume. It would, therefore, only be necessary to add sufficient sugar to increase the Brix to 24° or 25°.

The juice from grapefruit and oranges was prepared by reaming on rapidly revolving burrs. This beats in considerable air which the yeasts need for their growth and development. The juice was then screened by means of a screen revolving about 80 R. P. M. Juice from tangerines could not be extracted by this method. Grinding the whole fruit was not satisfactory, for not only do citrus oils have a slight antiseptic effect, but inclusion of the peel and rag renders the wine intensely bitter. Table III shows the effect on the alcohol content of orange wine by the addition of different quantities of orange oil. A pure yeast starter was used.

Theoretically, the bouquet of the wine depends upon the type of yeast used. All wines prepared with distiller's yeast had an objectionable "yeasty" taste. Those made by using wine yeasts were definitely better. However, no conclusive evidence has as yet been obtained to indicate which wine yeast yields the better tasting product. The Champagne yeast is a more rapid fermenter than either the Burgundy or Hansen. We have, therefore, used the former in the preparation of brandies.

Yeast is added in the form of a "starter." This is prepared by adding, under aseptic conditions, a small amount of the culture to 100 cc of sterile orange or grapefruit juice. In 48 hours this is in active fermentation and is added to one liter of sterile orange or grapefruit juice. Forty-eight hours later this is in active fermentation and is added to 10 liters of juice, which need not be sterile. The propagation of the culture should be

TABLE III
EFFECT OF THE ADDITION OF COLD-PRESSED ORANGE OIL ON THE ALCOHOL CONTENT OF FERMENTED ORANGE JUICE

<table>
<thead>
<tr>
<th>Cold Pressed Orange Oil added, Per Cent. by Volume</th>
<th>Alcohol Per Cent. by Volume in the fermented Juice</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00</td>
<td>5.1</td>
</tr>
<tr>
<td>0.01</td>
<td>5.1</td>
</tr>
<tr>
<td>0.03</td>
<td>5.3</td>
</tr>
<tr>
<td>0.08</td>
<td>4.8</td>
</tr>
<tr>
<td>0.10</td>
<td>1.6</td>
</tr>
<tr>
<td>0.40</td>
<td>0.6</td>
</tr>
<tr>
<td>0.80</td>
<td>0.9</td>
</tr>
</tbody>
</table>
carried out in such a manner as to exclude contamination by wild yeast, bacteria and mold. The 10 liters of actively fermenting juice are sufficient to start 100 liters of juice. It is preferable to inoculate the main batch of juice with a starter which is not more than 48 hours old.

In the preparation of wine from grapes it is not unusual to carry on the fermentation at temperatures as high as 32° C. (90° F.) and it is usually around 27° C. (80° F.). Sound wine from citrus cannot be made at such high temperatures. Fermentation should be carried out at 16° to 18° C. (60-65° F.) and possibly lower. It is important to have a slow fermentation to conserve the fleeting aroma of citrus. Rapid fermentation and high temperatures encourage the development of organisms unfavorable for the production of sound wines. High temperatures also decrease the per cent. of alcohol in the wine as shown in Table IV.

### TABLE IV

<table>
<thead>
<tr>
<th>Temperature ° C.</th>
<th>Organism</th>
<th>Per Cent. Alcohol by Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>28</td>
<td>15.1</td>
<td>16.4</td>
</tr>
<tr>
<td>35</td>
<td>7.7</td>
<td>9.0</td>
</tr>
</tbody>
</table>

During fermentation the temperature of the juice may increase as much as 12° C. (21° F.) and may even rise sufficiently high to inhibit normal growth of the yeast. It is therefore of vital importance to have some means of artificially cooling the fermenting juice.

Active fermentation is usually completed in from eight to ten days. At the end of this time the yeast will settle as a sludge to the bottom of the fermenting vat. This sludge may be used to start another batch, but since it contains organisms other than the pure culture of yeast first added, it is not advisable to use it more than twice. It is then necessary to start another pure culture as already described.

The wine will be cloudy and in a majority of cases will never become sparkling clear even upon long standing. Clarification has been attempted by egg white and by a mixture of tannic acid and gelatine. These attempts were unsuccessful. In the laboratory, we have clarified by means of suction in combination with a filtering aid such as filter cel according to Caldwell (4). About three per cent. of filter aid is added, based on the weight of the wine. This will give a clear product, but it is preferable to subject it to further clarification to give a final “polish.” This phase of the problem is still under investigation. Commercially, the first filtration would be by means of a plate and frame press, the wine being pumped through the press with compressed air. The final “polishing” of the wine would be accomplished by another type of filter press.

After filtering, the wine should be aged at a uniform temperature at about 60° F. in plain oak barrels, which have been previously thoroughly steamed. The wood will absorb a portion of the wine, so it is necessary to frequently inspect the barrels and keep them well filled with wine. Aging in wood is said to allow an optimum interchange of air through the pores of the wood, facilitating the oxidation of aldehydes to acids which upon esterification give wine its characteristic bouquet. In some cases it has been found advantageous to add a small amount of cold pressed orange oil to the orange wine at the time of bottling. Citrus wines aged in glass are distinctly inferior to those aged in wood.

Grapefruit wine is intensely bitter, especially if the wine is dry. The “home-brewer” has in the past attenuated this bitterness by adding sugar. However, the amount that must be added to mask the taste renders the wine extremely sweet. Clarification of the juice before fermentation almost entirely removes the bitterness and by subsequent aging the wine in wood, the bitter taste is reduced to a minimum.

Thus far, all attempts to prepare a dry wine from citrus have met with failure. Dry wines from oranges, tangerines and tangelos are bitter and unpalatable. By a dry wine is meant one containing less than one gram of sugar per 100cc of wine. We have found that 3 or 4 grams of sugar will render the wine more palatable.

Encouraging results have been obtained by fortifying with citrus brandy, increasing the alcoholic content of the wine to about 20 per cent. by vol-
By adding the correct amount of cane sugar and glucose, and coloring with caramel, a product is obtained which very closely approximates Port.

Experiments have not progressed far enough to warrant definite conclusions as to the proper length of time for aging.

It has been tentatively estimated that it would cost $0.42 to manufacture a gallon of citrus "wine." This is estimated upon the basis of fruit costing $0.45 a field box and a plant representing an investment of $15,000.

**BRANDIES AND WINE SPIRITS**

Brandy is made by distilling wine, or the fermented juice of other fruits, such as apples, peaches, blackberries, etc. The best brandy (Cognac) is made by distilling a good quality of white wine. Brandy contains from 47 to 54 per cent. alcohol by volume.

In the preparation of citrus brandies, sugar is added to the juice and fermentation allowed to proceed in the same manner as wine. In some of our experiments corn sugar was used because it is cheaper than cane sugar and also because fermentation is more rapid. Fermentation is complete in from four to eight days. Pure cultures of yeast are used as in the case of wines.

The fermented juice is distilled, using a still provided with a rectifying column to trap the higher boiling fractions, allowing the esters and low boiling fractions to distil over. In our experimental still and rectifying column we have continued distillation until the alcohol content of the distillate was about 25 per cent. by volume. The receiver was then changed and the distillate collected until it contained 15 per cent. alcohol. This last fraction was then added to the next batch to be distilled. The first fraction was diluted with distilled water to 101 proof. In laboratory experiments, operating a 20-gallon still, the distillation loss averaged about 7 per cent.

Brandies should be aged in plain oak barrels, which have been previously thoroughly steamed. The desired amber color is obtained with caramel. Charred barrels color the product too deeply and harm the bouquet so that after a short time the product has more of a whiskey than a brandy taste.

Wine spirits from citrus are prepared in the same manner as brandy, but rectified to give an alcoholic content of from 85 to 95 per cent. by volume.

In general, a gallon of 100 proof brandy may be obtained from a field box of grapefruit or oranges by adding sugar in the proportion of two pounds per gallon of juice. Assuming that fruit costs 45 cents a field box and the distilling plant represents an investment of $100,000, it would cost about $1.25 to make a gallon of brandy. To this should be added $2.00 for Federal tax, making a total of $3.25. This figure includes material cost, labor and all factory overhead.

**CORDIALS AND LIQUEURS**

Cordials and Liqueurs from citrus have been made by adding sugar, essential oils and water to rectified wine spirits. Orange, lime, lemon, tangerine and grapefruit cordials have been prepared, using the oil from the peel of these fruits. The addition of naringin, the bitter glucoside in the peel of grapefruit, to grapefruit cordial imparts to the product a bitter taste so characteristic of the fruit.

Pleasing drinks have been prepared by adding combinations of citrus oils, anise and different herbs to rectified wine spirits.

**FURTHER PROBLEMS TO BE CONSIDERED**

There is still considerable work to be carried out in the preparation of wines and liqueurs from citrus. For instance, we do not know the most favorable yeast for the production of citrus wines and brandies. This, perhaps, is the most important problem. Nor are we certain of the optimum temperature at which fermentation should proceed. We do know that this temperature should be lower than used for grape wines. Further work must be carried out, using cane and raw sugars, and corn sugar. Storage conditions must be investigated. We have only a cursory knowledge of the proper aging of citrus wines. Artificial aging should be investigated. Clarification must be the subject of further careful study, for when citrus wines are cleared as described in this paper there is danger of losing some of the bouquet. As already mentioned, citi-
rus wines lack body and this phase of the problem calls for further investigation. Production of dry wines from citrus has thus far met with failure. The wine is bitter and totally lacking in character. This problem calls for more intense research. We cannot answer definitely the question relative to the proper acidity of the fruit to be used for making wine.

In view of the above fact, caution should be exercised by those contemplating at this early stage of the investigation, production of citrus wines on a large scale. It is also probable that the public will have to be educated to cultivate a taste for citrus wines.

SUMMARY

Tentative results indicate that a wine of pleasing aroma and taste can be prepared from oranges and tangerines by adding sugar to increase the sugar content of the juice to about 25 per cent., and then inoculating with a pure culture of wine yeast. Fermentation should be carried out at a temperature of approximately 60° F. After active fermentation has been completed the wine is clarified by means of a filtering aid.

Grapefruit yields an intensely bitter wine. Proper clarification before fermentation, and prolonged aging in wood greatly attenuates this bitter taste.

Dry wines prepared from citrus have thus far been unsatisfactory. Tentative results indicate the finished wine should have at least 4 per cent. total sugars.

A method of preparing citrus cordials, brandies and liqueurs has been described.

LITERATURE CITED


THE WORK OF THE FLORIDA GROWERS AND SHIPPERS LEAGUE

J. Curtis Robinson, Orlando

The Florida State Horticultural Society has held during the last three days, its Forty-seventh Annual Meeting. No doubt some of those in attendance during this session helped to organize the Society or were present at many of its first meetings. The organization I have the honor to represent, The Growers & Shippers League of Florida, is young compared with yours, but it has been the servant of the growers and shippers of Florida citrus fruits and vegetables for the past decade, having celebrated our tenth anniversary last January, when at our annual meeting and dinner we were proud of the ten twinkling candles on our birthday cake.

I know that great benefit may be obtained by those members of your society, engaged in producing citrus fruit in Florida, who will take the time to attend your meetings and listen attentively to the many interesting and enlightening papers read by those trained in their particular specialty. Men, who have spent years in research for the cause of certain of the ills of citrus trees, can give you the benefit of their study and investigation. If you in turn heed the warnings they give and apply the remedies they recommend, you may, before too late, nurse an ailing tree back to normal.

By applying the right kinds of fertilizer and insecticides you can produce clean, high quality fruit and by doing so place yourselves in position to command the best available prices.

After high quality fruit is produced, the next