ECONOMIC MICROBIOLOGY

Volume 3

ECONOMIC MICROBIOLOGY
Volume 1

ALCOHOLIC BEVERAGES

edited by

A. H. ROSE
School of Biological Sciences
University of Bath,
Bath, England

1977

ACADEMIC PRESS
LONDON NEW YORK SAN FRANCISCO
A Subsidiary of Harcourt Brace Jovanovich, Publishers

PREFACE TO THE SERIES

Controlling and exploiting the World's flora and fauna have been fundamental to Man's colonization of this planet. His ability to regulate the activities, both pathogenic and saprophytic, of micro-organisms, and to go on to harness microbial activity in the manufacture of foods and chemicals represents a truly outstanding achievement especially when one remembers that microbes represented an invisible activity or agent until microbiology became established as a science during the latter half of the last Century. Only then did it become apparent that Man's very existence depends on microbial activity.

This multi-volume series aims to provide authoritative accounts of the many facets of exploitation and control of microbial activity. The first volume describes production of alcoholic beverages, and in the second and third volumes there are accounts of the microbiological production of commercially important chemicals. Production of microbial biomass is the subject of the fourth volume, and in the fifth there are accounts of production of enzymes from micro-organisms and of industrially-important chemical conversions or reactions mediated by microbes. Later volumes will deal with biodeterioration caused by microbes, sewage purification and the microbiology of foods. Throughout the volumes, emphasis is placed on the chemical activities of micro-organisms for it is these activities which affect with such impact the activities of man. It is hoped that the series will provide an adequate testimony to the unique relationship which Man has forged with his smallest servants.

January, 1977 ANTHONY H. ROSE

CONTENTS

1. History and Scientific Basis of Alcoholic Beverage Production

A. H. ROSE

2. Beer

ANNA M. MacLEOD

5. Fruit and Honey Wines

ANDRZEJ JARCZYK AND WIESLAW WZOREK

Department of Food Technology,
Agricultural University of Warsaw, Warsaw, Poland

I. INTRODUCTION

Fruit wines have for many years now been an important product obtained from fruit processing. Like the term 'grape wine' or 'wine', the oenological product obtained from fruits is designated 'fruit wine'. Production of fruit wines has gained a foothold in many countries, particularly those characterized by a rougher climate in which cultivation of the grape vine cannot be developed.

The term 'fruit wines' is hard to define, particularly as regards distinguishing it from fermented grape musts with a content of several per cent alcohol, and from cider and perry, all products with a long standing tradition (Warcollier, 1928; Charley, 1954). Considering that legal rules covering fruit wines, as enforced in many countries at the present time, recognize as a fruit wine any fermented fruit must with at least 8–9% alcohol content by volume, the authors have decided not to deal in this chapter with the production of cider, perry or other fruit beverages with an alcohol content below 8–9%. Moreover no further consideration has been given herein to the relatively limited production of wines of pineapples, oranges, grapefruits (Amerine and Cruess, 1960), or to those derived from other tropical fruits like dates or figs.

The authors have discussed wines made from fruits typically originating from regions with climatic conditions most close to those of Central Europe. Such fruits include mainly apples, currants (and other berry fruits) as well as certain stone-fruits, such as plums or cherries.

Production of fruit wines differs essentially from that of grape wines, particularly with regard to the highly differentiated raw material, the need for sweetening and dilution of fruit musts, and the resulting differences as regards the process of fermentation and mellowing.

II. GENERAL INFORMATION

Fruit wines are beverages obtained by alcoholic fermentation of fruits (with the exception of vine grapes) or of juices thereof, with an alcohol content amounting to between approximately 8–9 and 18% (v/v), and sometimes even more. Fruit wines are made mainly out of pome fruits, berry fruits and stone fruits, and less frequently out of citrus and other fruits.

The above definition does not include alcoholic fruit—beverages like cider or perry, since these have a lower alcohol content than fruit wines, of the order of 5–7% (v/v) because sucrose is not added to the juice. The desired strength of fruit wines is obtained by sweetening prepared fruit juices with sugar.

Many criteria have been adopted as valid in connection with the classification of fruit wines. Firstly they are divided, depending on the colouring, into white and red wines, usually with no distinction being made to pink (or rosé) wines (Wzorek, 1973). The basic components which affect the properties of wine are the sugar and the alcohol contents. Detailed wine classification is based upon a differentiation in the contents of the above components. In Poland, for example, a distinction is drawn between dry wines, containing between 0 and 10 g sugar/l and 9–11% alcohol by volume; semi-dry wines, containing from 20 to 30 g sugar/l and 10–12% alcohol by volume; slightly sweet wines, containing 45 to 65 g sugar/l and 11–13% alcohol by volume; sweet wines, containing 80 to 110 g sugar/l and 12–14% alcohol by volume; and very sweet wines with a sugar content in excess of 120 g sugar/l and an alcohol content of the order of 13–18% by volume. Dry and semi-dry wines are designated also as table wines, while those slightly sweet, sweet or very sweet are known as dessert wines. A similar classification is adopted, furthermore, in other countries which is specified by the pertaining standards (GOST 17292-71—Vina plodovo-jagodnye, 1971; GOST 5400-70—Vina plodovo-jagodnye naturalnye, 1970; ČSN 567810—Ovocne vina, PN-71/A-79121 Wino owocowe, 1971); Tables 1 and 2. A distinction is also made for carbonated fruit wines, following a mechanical saturation with carbon dioxide, and sparkling wines containing carbon dioxide obtained by alcoholic fermentation. A separate group is represented by herb wines (including vermouths) with certain added herb and spice ingredients. As far as the commercial turnover is concerned, a distinction is made between ordinary and fine wines, the latter being marked by constant properties and by a higher quality. Dry and semi-dry fruit wines are made in only limited quantities. Also wines produced out of a single brand of fruits are rather scarce.

The chemical composition of typical fruit wines produced at present in Poland is shown in Table 3. Table 4 lists the chemical composition of certain fruit wines made in the U.S.S.R. The chemical composition of wines produced in the German Federal Republic is listed by Wucherpfennig (1969, 1971).

Certain of the chemical components listed in Tables 3 and 4 have an influence upon the quality of fruit wines. Such components include the non-sugar soluble extract, ash and volatile acids.

Table 1

Standards for analytical data for some fruit wines produced in U.S.S.R. (Norma GOST 17292-71—Vina plodovo-jagodnye)

Wine	Alcohol (% by volume)	Total sugars (g/100 ml)
Sparkling wines	11.5	5
Carbonated white wines	11	7
Carbonated rosé wines	10–11	10
Table dry wines	10–13.5	0.3
Table white wines with sugar content up to 1% (w/v)	12	1.0
Table slightly sweet wines	10–13	5–8
Sweet unfortified wines	13–14.5	10–16
Liqueur-type unfortified wines	14	25
Fortified strong wines	16–18	7–10
Fortified sweet wines	14–16	10–18
Liqueur-type fortified wines	13–16	20–30
Sweet honey wines	12–16	16–20
Liqueur-type honey wines	14	30
Aromatized strong wines	16–18	8–10
Aromatized sweet wines	16	13–16
Liqueur type aromatized wines	16	20

Table 2

Analytical data for some fruit wines produced in Czechoslovakia (CSN Standard 567810—Ovocná vina)

Wine	Alcohol (% by volume)	Total sugars (g/100 ml)
Table wines	10	2.0 (max)
Slightly sweet wines	12	3.0–8.0
Sweet wines	14	10.0

Standardization of non-sugar soluble extracts and ash content is aimed at preventing excessive wine dilution. The chemical component that is related to the quality of the raw material used and of the hygiene in the technological process involved is the volatile acidity. With general technological and sanitary requirements being adhered to, and with the correct fermentation course, the volatile acid (expressed as acetic acid) does not usually exceed 1.2 g/l for white and 1.6 g/l for red wines.

Table 3

Composition of some Polish fruit wines. From data supplied by the Warsaw Institute of Fermentation Industry (1974)

Type of wine	Alcohol (% by volume)	Total sugars	Non-sugar soluble	Acid (as malic acid)	Volatile acidity	Ash
		(g/l of wine)				
White slightly sweet	12.3	64.7	19.1	5.1	0.87	1.9
Red slightly sweet	12.6	66.9	22.2	6.6	0.9	2.2
White sweet	12.9	103.1	23.2	5.6	0.82	2.0
Red sweet	13.0	104.0	30.3	7.3	0.95	2.9
White very sweet	14.1	135.3	22.9	6.7	0.65	2.2
Red very sweet	13.5	131.8	25.9	7.0	0.75	2.7
Single fruit wines						
Apple, slightly sweet	12.4	62.0	18.0	6.2	1.10	1.8
Apple, sweet	13.0	101.8	23.7	5.4	0.85	2.0
Red current, slightly sweet	12.4	72.2	22.1	6.9	0.90	2.0

Table 4

Composition of some fruit wines produced in U.S.S.R. (Mitjukov *et al.*, 1965)

Wine	Alcohol (% by volume)	Acidity (g/l)	Total sugars (g/l)	Non-sugar solubles (g/l)
White dry	12.3	7.4	15.6	22.0
Red semi-dry	12.7	8.5	33.7	30.1
White slightly sweet	12.8	7.3	65.7	25.0
Red slightly sweet	13.1	8.4	59.3	31.5
White sweet	13.3	7.6	104.9	30.6
Red sweet	13.6	8.7	97.9	35.1

The concentration (in g/100 l) of non-sugar solubles is calculated using the formula:

$$E_t - [S_r + (S_t - S_r) \cdot 0.95]$$

in which E_t is the value for the concentration (g/100 ml) of soluble solids, S_r of reducing sugars (g/100 ml), and S_t of total sugars (g/100 ml).

The U.S.S.R. and Poland are ranked among the two World leading fruit-wine makers. Annual output of fruit wines amounted in the U.S.S.R. in 1968 to 323 million litres, with plans for 1975 providing for 480 million litres (Trofimenko, 1969) and, in Poland, to 160 million litres in 1972 (Rocznik Statystyczny, 1973). Other European countries are producing smaller quantities of fruit wines (cider not included). For example, the German Federal Republic produces approximately 15 million litres (Korth, 1973; Skibe, 1969). Large-scale wineries in operation at the present time are offering a production capacity of up to 10 million litres of fruit wine annually.

III. RAW MATERIALS

Basic raw materials for production of fruit wines are fruits of different varieties. Used most frequently are fruits typical of countries with a moderate climate (Golomštok and Šapiro, 1962). Apart from the fruit classifications as adopted in the wine-making industry, namely into stone, berry and pome fruits, fruits can also be divided, for practical reasons, into cultivated fruits (for example apples, currants, strawberries) and those growing in the wild (for example bilberries, blackberries, bog bilberries, elderberries, rose hips, bird

Table 5

Chemical composition of edible parts of several fruits used in wine making. From Pijanowski *et al.* (1973)

Fruit	Content (per cent weight of) Water	Dry matter	Insoluble substances	Total sugars	Sucrose	Invert sugar	Nitrogenous compounds (N × 6.25)	Acid (as malic acid)	Cellulose	Pectin (as calcium pectate)	Tannins	Ash
Apples (*Pirus malus*)	85.0	15.0	2.0	10.0	2.5	7.6	0.3	0.6	1.3	0.6	0.07	0.3
Apricots (*Armeniaca vulgaris* Lam.)	86.0	14.0	2.5	6.7	3.6	2.9	0.8	1.3	0.8	0.9	0.07	0.7
Bilberries (*Vaccinium myrtillus*)	86.5	13.5	3.7	6.6	0.2	6.4	0.8	0.8	2.3	0.6	0.22	0.3
Blackberries (*Rubus fruticosus*)	85.0	15.0	6.2	5.5	0.5	4.9	1.3	0.9	4.0	0.7	0.29	0.6
Black currant (*Ribes nigrum*)	80.3	19.7	6.0	7.0	1.8	5.0	1.7	3.0	4.0	1.1	0.39	0.8
Cherries (*Prunus cerasus*)	83.1	16.9	2.2	9.7	0.5	9.2	1.0	1.3	0.3	0.25	0.14	0.5
Cowberries (*Vaccinium vitis idaea* L.)	83.6	16.4	4.1	8.7	0.5	8.2	0.7	2.0	1.8		0.25	0.3
Currant (*Ribes rubrum*)	83.8	16.2	7.2	5.3	0.2	5.1	0.5	2.4	4.5	0.6	0.21	0.7
Gooseberry (*Ribes grossularia*)	85.5	14.5	4.7	6.1	0.5	5.6	0.5	1.9	2.7	0.8	0.09	0.5
Peaches (*Persica vulgaris* Mill)	84.5	15.5	3.0	7.8	4.3	3.3	0.7	0.8	1.0	0.7	0.10	0.6
Pears (*Pirus communis*)	83.5	16.5	3.0	9.5	1.3	8.2	0.4	0.3	2.6	0.5	0.03	0.4
Plums (*Prunis domestica*)—and others	82.0	18.0	2.4	9.3	1.8	7.3	0.7	1.2	0.6	0.8	0.07	0.5
Raspberries (*Rubus idaeus*)	84.0	16.0	9.1	4.7	0.2	4.5	1.4	1.6	5.7	0.55	0.26	0.6
Rose hips (*Rosa canina* L.)	70.0	30.0	8.0	7.0	-	—	1.5	2.0	—	—	—	1.6
Strawberries (*Fragaria vesca, F. virginiana*)	88.5	11.5	2.2	6.5	0.6	5.9	0.7	1.0	1.8	0.55	0.20	0.7

cherries; Kulešova 1959). The chemical composition of certain fruits used for the making of wine is presented in Table 5.

Certain of the cultivated fruits may grow wildly (for example apples), added to which certain wild fruits (such as rose hips) may be grown on plantations. Fruits grown in the wild are noted for a higher content of acid, of vegetable tannins, and by a stronger aroma, and present for the above reasons a valuable raw material for production of wine. Dried fruits can be used for the production of wine (Amerine and Cruess, 1960).

The next basic raw material, indispensable for the production of practically all types of wine, is sugar. Used usually for this purpose is sucrose obtained from sugar beet or from sugar cane.

Water used for diluting must in the making of certain fruit-wine brands must meet the requirements demanded generally of drinking water. Furthermore, wine production from only slightly sour fruits involves an after-acidification with edible organic acids, like citric acid, tartaric acid and lactic acid. Auxiliary agents used in the production of fruit wines include: pure yeast cultures, carbon dioxide, sulphur dioxide, sulphites, filter aids (asbestos, cellulose, diatomaceous earth), clarifying agents (bentonites, egg white, tannin, gelatin, silica gel, activated carbon), ascorbic acid, nitrogen, pectolytic preparations, and other substances (Jakob, 1971).

IV. TECHNOLOGICAL PROCESSING

A. Pressing

Fruits are delivered to the winery in cases, chip baskets, or sometimes in bulk by lorries or railway cars. The raw material is sorted out on conveyor belts, and washed in washers of various types. Primary washing of a raw material, such as apples, is sometimes commenced while in the flumes when water handling is used in the process.

With an increased must yield in mind, fruits are disintegrated prior to pressing, using disintegrating equipment of various types. In some cases, parts of the fruit that can cause a deterioration in the flavour and aroma of ready must (shanks) are removed prior to disintegration. For many years soft, mainly berry, fruits have been crushed with the use of crusher equipment, while hard fruits (such as apples and pears) have required the use of hammer mills. The present practice provides for an even more frequent application of disintegrators, mostly of the Rietz type.

Most commonly in use for pressing the majority of fruits are the hydraulic rack-and-cloth presses in which pulp is filled into cloths which are then ploughed in by press racks made of wood, aluminium or plastics. The pressure obtained inside rack-and-cloth presses, within the layers of the pulp subjected to pressing, is of the order of up to 30 kg/cm^2. Despite the labour involved in loading the pulp and offloading the pomace, the rack-and-cloth press finds a ready application, with a high pressing output that amounts in the case of apples to approximately 75% of the total available. Basket presses find a limited application with fruit pressing, because of the low output of must. Useful, on the other hand, for pressing of fruit of various varieties, have been the Bücher–Guyer modified basket presses incorporating a draining system for rendering the pulp fluffy in the course of the pressing action, and a mechanized attachment for feeding pulp and offloading pomace (Fig. 1). The processing capacity of a Bücher–Guyer type HP-5000 press amounts to 5,000–6,000 kg for apples, and up to 34,000 kg for black currants per hour, with the volume capacity of the basket of 6 m^3 (Mrożewski and Chwiej, 1969).

Presses offering a continuous action, namely screw, band, band-and-roller presses, as well as those operated on the principle of continuous vacuum filters, find a limited application with fruit pressing, because of their low working output, and particularly in the case of worm presses, of a considerable content of slurry in the juice obtained.

Pomace pressing in order to increase the yield of must is seldom applied because of a low profitability. The pressing yield can, on the other hand, be boosted effectively by adding pectolytic preparations in doses of 0.1–0.5% (Rzędowski, 1956; Pijanowski *et al.*, 1964; Daškevič and Vol, 1966), as well as by pressing a primarily fermented pulp.

An ever more frequently applied practice involves pressing the pulp following a previous warming up to a temperature of approximately 80–85°C, with simultaneous addition of pectolytic prepa-

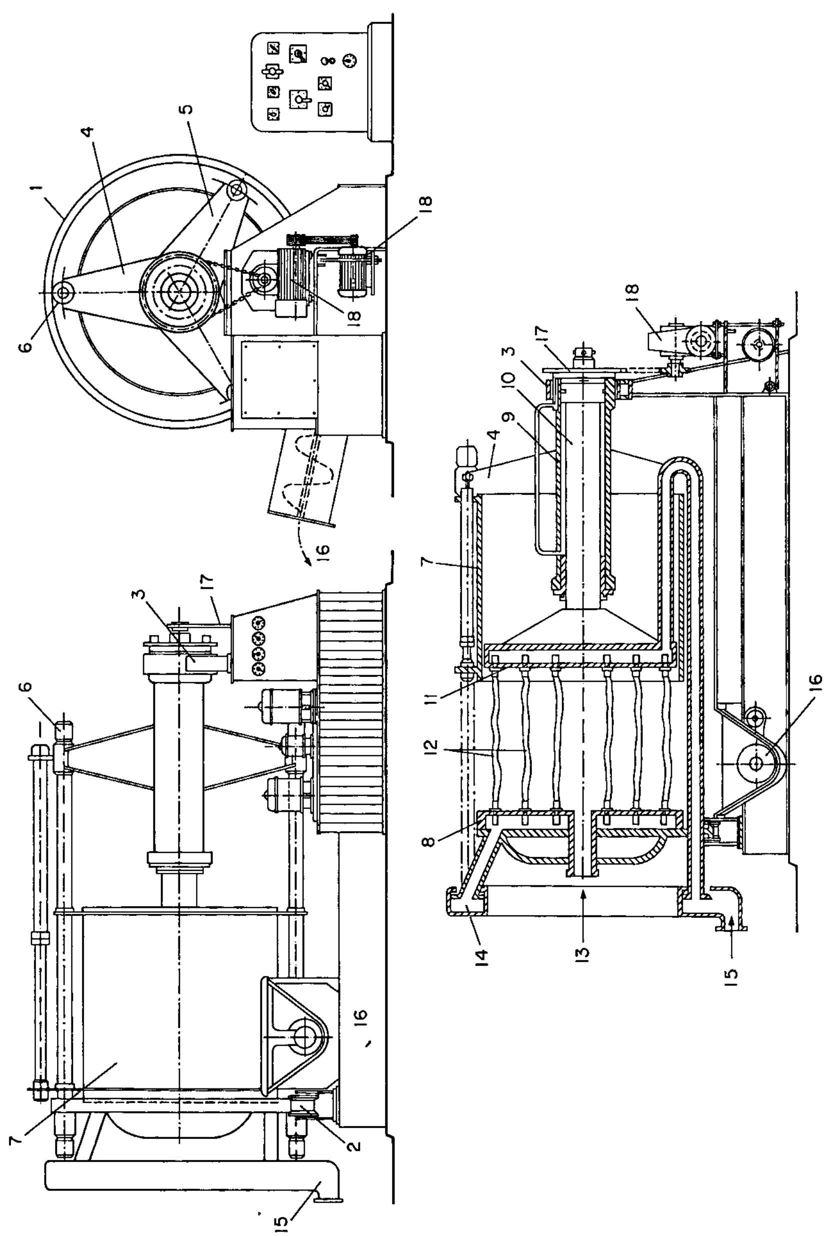

Fig. 1. Diagram of a Bücher-Guyer type HP-5000 press (Mrożewski and Chwiej, 1969). 1, indicates a horizontal rotary basket; 2, rolls; 3, ball bearing; 4 and 5, resistance blocks; 6, turnbuckles; 7, pressure-resisting shell; 8, pressure plate; 9, cylinder; 10, piston; 11, pressing plate; 12, draining system; 13, feeding; 14, juice collector; 15, juice outlet; 16, pomace worm; 17, drive of basket; and 18, electric motor.

rations following a partial cooling off. These measures are taken in order to boost the pressing output, and at the same time to obtain a more intensely coloured must.

B. Conservation and Storage of Fruit Must

Not all of the must obtained by pressing is used directly for production of prepared wine juices. Part of the must is reserved for storage, to be used as required for the making of prepared wine juices.

Must earmarked for storage is purified primarily by straining, centrifuging, sometimes by filtration, frequently by pasteurization (thereby giving the possibility of an aseptic storage), then fixed by adding a preserving agent. The dose of preservative, mostly sulphur dioxide, must be selected so as to protect must against the effects of micro-organisms over the period of foreseen storage.

Doses of sulphur dioxide applied on an industrial scale vary considerably, and oscillate within the limits of 400 to 1200 mg/l, depending on the storage period scheduled. Sulphur dioxide is mostly administered in a gaseous form, with the use of a continuous-action batching (sulphitating) equipment. Dosing can also be effected in the form of, say, a 6% aqueous solution of sulphur dioxide, as well as of sulphites, the most handy of which is the potassium pyrosulphite ($K_2S_2O_5$). Preserved must is stored in metal, concrete or wooden tanks, properly protected, for a period of several months. A trend is noted, at the present time, towards a limitation in the use of sulphur dioxide for preserving fruit musts for wine-making purposes.

Preserving fruit must for wine-making purposes with the use of carbon dioxide under pressure is at present seldom used. Fruit musts for the production of wine are, on the other hand, concentrated some 7-fold in volume following the removal of pectic substances and filtration, and then stored in the form of a concentrate at a temperature of 5–7°C. Prior to the processing of must into prepared wine juice, the concentrate is diluted with water as required, and sometimes mixed with non-concentrated must (Popova, 1960). While diluting concentrated juices, an additive is sometimes used, usually during the final stage of fermentation, made up of a condensate of previously separated aromatic substances, and this is, in certain countries, legally required. Addition of chemical preservative agents is made superfluous owing to the concentration of the must, and this permits also a decrease in the storage-volume capacity. Masior *et al.* (1972a) recommend adding bentonites to prepared juices of concentrated musts.

Application of sorbic acid for the preservation of fruit musts used for making prepared wine juices has found little application in the wine industry (Burkhardt, 1973), largely because of difficulties encountered in removing it from preserved must.

C. Preparation of Fruit Must for Fermentation

1. Desulphiting

Operating a winery fermentation with continuously prepared juices from preserved fruit musts necessitates removal of sulphur dioxide. Desulphiting of must involves cleaving bonds between carbohydrates and sulphurous acid which results in the greater part of the sulphur dioxide escaping from the preserved must. The process used most commonly and effectively in order to lower the concentration of sulphur dioxide in must is aeration usually following a preliminary warm-up. Owing to the high volatility of sulphur dioxide, and also to partial oxidation to give sulphurous acid, the sulphur-dioxide content of must decreases. Lowering the concentration of sulphur dioxide may also be obtained by passing neutral gases through the must. Nitrogen gas is often used, but carbon dioxide is seldom used on an industrial scale. Excess sulphur dioxide can furthermore be removed by warming *in vacuo*. Desulphiting by warming has the effect of losing aroma and alcohol (in partially incipient fermented musts), and produces an off-flavour that accompanies boiling.

Oxidation of sulphur dioxide with hydrogen peroxide, to give sulphur trioxide, is not recommended, as desulphiting effected by this method deteriorates the flavour and aroma of the must.

Installations to facilitate desulphitation of musts include desulphitators in which the separation of sulphur dioxide is performed in a continuous way, without losses of aromatic substances and alcohol. All methods of desulphiting are fairly difficult to perform.

2. Adjustment of Acidity

Fruit musts contain various quantities of organic acids, usually amounting to 0.3 to 3% (w/v). Ensuring that a correct course is taken during alcoholic fermentation, with the possibilities being minimized of infecting the prepared juice with a contaminant microflora and of ensuring the correct organoleptic features in the wine, necessitates raising the acidity of the prepared juice usually to 6–8 g malic acid equivalent/l. This requires the acidity of certain musts to be lowered, and rarely necessitates an addition of edible organic acids.

Lowering the acidity is most frequently effected by diluting must with water, thereby offering the chemical and microbiological features of good drinking water. Water-must, obtained as a result of secondary fruit pressing, may be used instead of water for this purpose. An effective and purposeful procedure to control the acidity of musts involves blending sour-must brands with those with a lower acidity. A certain lowering of acidity is obtainable, furthermore, by sweetening must with sucrose.

An excessive dilution of must is prevented by neutralization with calcium carbonate. Removal of oxalic acid from, say, rhubarb must by treating with calcium carbonate facilitates, to a high degree, the growth of yeast and the course taken by the alcoholic fermentation (Pijanowski and Wasilewski, 1955). Ion exchangers are known to be used on a limited scale, both for lowering (Begunovova and Zacharinova, 1960) and increasing the acidity of must (Agabal'janc and Drboglav, 1960).

Used mainly for increasing the acidity of must are citric, tartaric and lactic acids. It is sometimes necessary to acidify must during fermentation because of the excessive growth of *Schizosaccharomyces pombe* and a considerable drop in the malic-acid content (Čalenko and Korsakova, 1960). When the fruit-must fermentation is operated correctly, its acidity should not need to be lowered (Zacharina and Fridman, 1967).

3. Addition of Sucrose

A process typical of the production of fruit wines, unlike that of grape wines, is sweetening must prior to, and sometimes during, the fermentation. Sweetening is necessary because of the low content of sugar in the majority of fruits, particularly of those grown in rougher climate zones. Addition of sugar enables the fermentation to take its proper course, and ensures greater stability of the wine, due to the higher alcohol concentration. Sucrose is added in a dose amounting mainly to between 150 and 300 g/l of must.

Sugar to produce the final sweetness in ready wine should be added on completion of fermentation. Addition of 100 g of simple sugar (hexose) yields practically 44-47 g of ethanol (Pijanowski and Wasilewski, 1955). Sucrose may be added to must directly, or in the form of syrup which causes the prepared juice to become additionally diluted. With a high rate of addition of sucrose, and the concentration in must exceeding 25%, difficulties may be experienced in prepared wine-juice fermentation. It is for this reason incorrect, in connection with strong and sweet wines that require a sugar dose of the order of 300 g per litre of must to give some unfermented sugar, to add the entire sugar batch at once. Sugar is instead in such cases added in two to three portions (Pijanowski and Wasilewski, 1955). Fermentation of must containing a high concentration of sugar would cause most frequently an excessive increase of volatile acidity. Sugar is dissolved in separate tanks, with the use of manual or mechanical agitation action.

4. *Preparation of Nitrogenous Yeast Food*

Must of fruits, particularly of currants, strawberries and of hedge rose, and especially following a strong dilution, contain an excessively low concentration of nitrogenous compounds which are indispensable for the propagation of yeast. Even an undiluted apple must frequently contains an insufficient concentration of nitrogenous compounds, while musts of bilberries suffer a permanent shortage in this respect.

Ammonium salts, like dibasic ammonium phosphate ($(NH_4)_2HPO_4$) are used as nutrients, the latter compound offering at the same time the main source of phosphate that plays an important part in alcoholic fermentation. Also used are ammonium chloride, ammonium sulphate and ammonium carbonate. The dose of dibasic ammonium phosphate used usually amounts to approximately 0.1-0.3 g/l of must. Sometimes, hydrolysates of rye are used as a source of nutrient (Masior and Czyżycki, 1959), particularly with currant and rhubarb must, as well as yeast autolysates (Masior and Czyżycki, 1965).

5. *Preparation of Pure Yeast Starter*

The purpose of inoculating a prepared wine juice with a pure culture of wine yeast is the rapid production of alcohol to a concentration of more than 4% by volume, which decreases growth of any undesirable microflora, while ensuring a correct course of alcoholic fermentation. Use of suitable cultures enables favourable organoleptic features of the ready wine to be obtained. For this purpose, it is necessary to add, to every litre of must, approximately 100 million yeast cells (Wasilewski, 1958). An optimum content of dry matter of yeast in a yeast starter is 12.5 g/l (Hrončeк and Malik, 1973).

Preparation of a yeast starter requires the use of thoroughly pasteurized fruit must, sweetened with sugar to approximately 15% (w/v), a yeast culture in the form of an agar culture and special pastes. Yeasts are grown mainly in small volumes of must, amounting to 1-5% of the volume of the portion to be inoculated, and are added to some scores or some hundreds of litres of pasteurized and sweetened must, for a further propagation at 22-25°C. Thus, the yeast starter is the only material to be added to properly prepared wine juices. The two-stage preparation of a yeast culture lasts for four to six days. Yeast starter is usually prepared in premises reserved for this purpose, inside glass balloons, wooden vats, and in some plants, in special installations called propagators. A correctly fermenting prepared must may be used instead of a yeast starter. It is possible to use strains of *Saccharomyces oviformis* (Lipiec, 1966) for fermentation of fruit musts.

6. *Inoculation*

The dose of propagated yeast amounts to between 1% and 10% of the volume of fruit must, depending on the kind of must. Sometimes even smaller batches are deemed sufficient. Wasilewski (1958) recommends doses of yeast starter for various musts as indicated in Table 6.

Adding pure cultures in uncontrolled quantities may cause a highly turbulent fermentation of prepared juice, including frothing.

Table 6

Doses of yeast starter culture used for various musts. From Wasilewski (1958)

Must	Dose of yeast starter culture (l/hl)
Apple	1–2
Pear	2–3
Fruit musts containing an excessive concentration of sulphur dioxide	2–5 or larger
Berry musts	1–2
Cherry pulp	2

It is recommended, when adding yeast starter to prepared juice, to add sulphur dioxide simultaneously, in quantities of 30 to 150 mg/l, in order to suppress growth of any undesirable microflora. These doses of sulphurous acid would inhibit most effectively propagation of bacteria in fruit musts, particularly of acetic-acid bacteria, as well as growth of wild yeasts, especially those of the apiculate type.

Selection of the correct species of yeasts depends on the variety of the fruit, acidity of the must, and its sugar, tannin, and sulphur dioxide contents, as well as on the brand of wine. Production of strong wines requires the use of yeasts that tolerate a higher concentration of alcohol. With bilberry wine, fermentation in pulp means that consideration must be given to the resistance of yeasts to tannins. Propagation or starter yeast culture is mixed with must prepared previously, at a temperature usually higher than 12°C but not exceeding 20°C.

D. Fermentation

1. *Classical Fermentation*

Fruit must prepared as required is subjected to fermentation in containers made of various types of material including plastic, metal and concrete, or in casks (Matheis, 1973). The fermentation may be conducted in a continuous manner (Usov, 1964). Prepared wine juice is subjected to incipient fermentation (which lasts several days), effervescent fermentation, and after-fermentation, which lasts altogether for approximately 5 to 6 weeks. After-fermentation of strong wines lasts usually for a longer time, because of an inhibition of yeast activity due to the higher alcohol concentration. With the process being characterized by production of abundant froth, some one-fifth of the volume of the fermentation tank should be left empty. One more fermentation stage is singled out distinctly, namely the silent or secondary fermentation during which a lowering of acidity in young wines occurs due to the malo-lactic fermentation by bacteria.

The fermentation should be commenced at a temperature of 12–15°C which prevents the fermenting prepared juice from attaining an excessively high temperature that could weaken or even annihilate the wine yeast. One kilogram of sugar produces, during fermentation, approximately 133 kcal. A normally fermenting prepared juice should attain, during the period of peak fermentation intensity, a temperature of 20–25°C, and not higher than 28°C. When the alcohol content has increased by a few percent and when the fermentation rate has diminished, the temperature may drop below 20°C. The higher the fermentation temperature, the lower in general the ultimate alcohol concentration in the wine.

Problems in the fermentation process often result from using too low an initial temperature with the prepared wine juice, too high a concentration of sulphur dioxide, an insufficient nutrient content, and too low a yeast content (Wasilewski, 1958).

On completion of fermentation, young wine must be drawn off from the lees. Keeping wine on the lees would cause unpleasant off-flavours to develop, and increase the susceptibility to diseases. Drawing wine off the lees at a suitable time is particularly important with wines with a low concentration of alcohol and fermented at high temperatures.

2. *Cold Fermentation*

Fermentation of processed juice may be conducted at lower temperatures than those used in the classical fermentation (Masior *et al.*, 1972b). Lowering the fermentation temperature to 5–10°C requires the use of special cultures of wine yeast (cryophilic yeasts). Using cryophilic yeasts allows wine juices to be fermented even at unfavourable temperatures, without the need to heat the fermentation premises, or even in the open. Using cryophilic yeasts permits, furthermore, the possibility of obtaining a higher content of alcohol in the wine, while helping to preserve more effectively the volatile components of the fruit aroma. It also cuts down alcohol losses. Wines fermented at low temperatures are noted for better qualities of flavour and aroma. Cold fermentation lowers furthermore the rate of yeast autolysis.

Disadvantages of low-temperature fermentation include a slower rate of fermentation and a greater possibility of infection of the prepared juice, a more difficult clarification of the wine thus obtained and, sometimes, the occurrence of a yeast off-taste. Cold fermentation is not much used with fruit-pulp fermenting.

3. *Fermentation in Pulp*

For a more effective extraction of pigments contained in the peel of fruits like bilberries, black currants, cherries, blackberries, strawberries and elderberries, the pulp is subjected to fermentation prior to pressing. Fermentation in the pulp facilitates furthermore the extraction of must from the majority of fruits, particularly of plums and strawberries (Schanderl and Koch, 1972), and subsequent wine clarification.

What with the relatively large number of micro-organisms on the surfaces of fruits, which with apples may amount to several hundred thousand mould spores and several million yeast cells per 1 cm^2 (Wasilewski, 1958), it is necessary to inoculate the pulp with a pure culture of wine yeast. Fermenting pulp is to a certain degree thus isolated from the environment by the evolving carbon dioxide which offers favourable circumstances for the alcoholic fermentation (Taguena, 1972; Žukov *et al.*, 1968).

In order to minimize contact of the fermenting pulp with atmospheric oxygen, it is recommended that special tanks be used holding solid parts of fruits underneath the surface of fermenting liquid. Wine yeasts find in fruit pulp an environment considerably more rich in nutrients as compared with musts; thus fermentation is in such an environment more intense. Fermented pulp is subjected to pressing, and the 'must' thus obtained is sweetened immediately and fermented further.

A recent development involves a heat treatment of pulp in order to extract pigment out of intensely coloured fruits more effectively (Nègre *et al.*, 1971; François, 1972), instead of fermentation in the pulp which has already been mentioned in the section on 'Pressing' (see p. 394).

E. Mellowing

1. *Natural and Accelerated Mellowing*

A young wine, on completion of fermentation, is characterized by the absence of a definite bouquet, with flavour and aroma undefinable, clarity and stability insufficient, and organoleptic qualities short of the standard required. These quality features are first obtained during the mellowing process, as well as a result of stabilization operations, and when methods of accelerated ripening are applied.

Mellowing of fruit wines is effected usually at a temperature of 7–15°C, inside metal, concrete or wooden tanks filled completely (by frequent replenishing) with racking performed at regular intervals. The first racking is usually effected one month after the drawing of wine from the lees, the next racking, on elapse of the successive two months as from that date. The successive operations are performed during the first year of mellowing, once every quarter, then once every half year during the following years. The purpose of racking from the lees is not solely to separate the wine from yeast cells and lees. It also serves to introduce into the cuve a certain amount of oxygen on which a correct mellowing process depends, and which is of particular importance in the case of tanks made of metal, concrete, or of plastics where there is not any diffusion across the tank walls.

Mellowing is usually accompanied by a further decrease in the acid content which involves bacterial transformation of malic acid into lactic acid and carbon dioxide, as well as of citric acid into citromalic acid with evolution of carbon dioxide (Carles *et al.*, 1958). Micro-organisms which effect these transformations are *Bacterium gracile* and *Micrococcus malolacticus*. The process of biological de-acidification cannot proceed too far in a grape wine that contains, apart from malic acid, tartaric acid. Apple wine, on the other hand, containing mainly malic acid, may acquire, as a result of an excessive malo-lactic fermentation, a too mild, hollow flavour (Pijanowski and Wasilewski, 1955).

Mellowing is the process in the course of which the bouquet is forming. Components that contribute to the bouquet include alcohols, aldehydes, acetals, ketones and esters. Production of these compounds may occur as a result of decarboxylation and deamination reactions. Alternatively, they may arise by purely chemical means as a result of oxidation and esterification. The components of the bouquet are formed early during the fermentation, whereas it is, for example the breed of yeasts and the content of amino acids that play an important part in the process (Wucherpfennig and Bretthauer, 1968a, b; Pisarnicki and Goliševa, 1971). The content of amino acids depends, in turn, for example, on the nature of the raw material and, in the case of fruits with a low content of nitrogenous compounds (bilberries, apples, currants following dilution), on the content of nitrogenous nutrients (Flanzy, 1965) and on the time during which the wine stays in contact with the yeast lees.

A significant part is played in the mellowing process by oxygen that diffuses across the staves of the casks, or is absorbed in the course of racking or other technological operations. A moderate access of oxygen is very essential throughout the initial period of mellowing (oxido-reduction processes).

Mellowing of dessert wines is effected without the application of sulphur dioxide. Wines with a flat aroma (including those from apples, white and red currants) display better organoleptic properties when there is an access of oxygen (for example during the initial stage of mellowing) which results in an off-taste of 'rawness' growing milder and the bouquet being more strongly pronounced. In the case of wines obtained from fruits noted for a strong aroma (for example black currants), it is advisable to ensure a minimum access of oxygen which for one thing allows preservation of the appreciated aroma, while, on the other hand, smoothing the excessively sharp shades thereof.

Mellowing dessert wines, while maintaining a slight content of free sulphur dioxide in order to preserve the aroma more effectively, seems of no avail, as the organoleptic properties thus obtained are inferior to those that follow mellowing with a slight access of oxygen

(Kurek, 1973). In the case of dry wines and semi-dry wines, it is sometimes a matter of routine to maintain a slight content of sulphur dioxide, usually of the order of 20–25 mg/l, in a free state in order to prevent undesirable oxidation processes.

The process of mellowing is accompanied furthermore by a decrease in turbidity caused by a precipitation of yeast and bacterial cells, pectic substances, unstable pigment–tannin fractions (possibly in combinations with iron), as well as of gums and slimes. Precipitation of tartaric acid-containing sludges is not observed in the case of fruit wines, and the occurrence of protein sludges is noted extremely rarely. The mellowing period does not exceed usually one year, with low-priced popular wines mellowing for 1–3 months (in Poland a minimum of two months), and fine wines for a much longer time (in Poland for a minimum of four months).

An accelerated fruit-wine mellowing process is also in use, and this mainly involves exposure to oxygen and warming-up, less frequently also with alternate cooling or subjecting wine to an accelerated sherryzation (see below; Pijanowski and Wasilewski, 1955).

Fruit wines present, generally speaking, an advantageous product for madeirizing (Eliasz, 1959, 1960). The madeirizing process is based on warming of wine at temperatures of 40–65°C, for 2–3 months, with some access of oxygen. It is advisable, for economic reasons, to warm up wines obtained from popular fruits like apples, plums or white and red currants, as the strong, characteristic bouquet so produced masks the aroma of the raw material. It is also desirable to enrich the wine in nitrogenous compounds in the form of an addition of wine-yeast lees to a concentration of 2.5% (Lewkowicz, 1973), since such wines have better organoleptic properties. In the case of raw materials with a slight tannin content, and of madeirization performed for example in metal tanks, it is a known practice to add oak wood shavings or wine tannin. Warming is effected usually with access of oxygen at a temperature of 55–65°C for 6–12 weeks, while it seems sufficient to maintain warming at temperature of 55°C for a period of six weeks.

Certain types of fruit wines are suitable for sherryzation. Schanderl and Koch (1972) recommend an accelerated sherryzation method for fruit wines, in which the bouquet is obtained within several weeks, under the action of wine yeasts in the oxidative phase. The yeast-cell lees (produced prior to filling in) gathers on the inner walls of the cask above the wine, or may also be maintained directly underneath the liquid level on an absorbant paper or other porous surface. Yeast films, owing to their limited contact with the liquid surface, stay slightly moistened, thus promoting an intense oxidation of alcohol and aromatization of wine. Most suited for this purpose are sherry yeasts (see p. 502). Other strains of wine yeasts may, however, also pass over to the oxidative phase. Control of temperature within the limits of 13–28°C, and of the duration of the process, permit various kinds and intensities of bouquet to be obtained. Good results are offered by sherryzation of heavy wines made from gooseberries, strawberries and rhubarb, although this process is not recommended for table wines made from apples, pears or cherries.

2. *Final Procedure*

The process of mellowing involves blending, flavouring, as well as other measures taken in order to ensure correct stability and clarity in the final product.

Blending improves the flavour and aroma of wine by mixing together wine brands of mutually complementary qualities, as well as ensuring standard properties in the final product. Wines with a flat aroma and other less advantageous features, such as in those made of rhubarb or apples, are usually subjected to blending with wines offering a strong aroma and highly appreciated organoleptic properties. Particularly suitable for blending are wines made from, for example, hedge rose, black currant, bilberry, cranberry and elderberry. Notwithstanding, a notion is prevalent (Pijanowski and Wasilewski, 1955) that blending of wines made from various fruit varieties should be limited in favour of a trend towards production of specific single-fruit wines.

Flavouring has the aim of improving the quality of wines, and correcting various physical and chemical properties, in compliance with the requirements as listed in the standard specifications. The most commonly applied operation is sweetening with sugar (sucrose). The sugar may be cold-diluted in wine, or warm-diluted in water reserved for this purpose. In the case of low acid content, the practice provides for adding a required amount of an edible organic acid, mainly citric acid and less frequently tartaric or lactic acid, and

it is to be noted that the legislation of many countries restricts the maximum amount of acid added to 1–3 g/l. A correct acidity in the wine is usually obtained by skilled blending, and subsequent acidification is effected mainly when there is an undesirable excessive biological de-acidification.

It is frequently necessary, in the course of production of fruit wines, to increase the alcohol content, a process which is effected by adding rectified spirit. The alcohol thus added 'harmonizes' with wine slowly, and its presence is then distinctly perceptible by organoleptic evaluation. It is for this reason desirable to carry out wine fortification towards the end of the fermentation process or directly following this process. Very good results are obtained as a result of diffusive fortification. Wine fortification was until recently the rule in all republics of the Soviet Union which practise fruit-wine production. Musts fermented down to 5–8% alcohol were fortified to 12–16%, and sweetened afterwards (Mitjukov *et al.*, 1968; Sosina *et al.*, 1968).

A frequently applied measure, particularly with dessert wines, is cross-dyeing, with the amber-brownish tinge being obtained mostly by addition of caramel, i.e. a product obtained by roasting sucrose or technical glucose at a temperature of approximately 210°C. An improvement in the colour of red wines is obtained frequently by the use of musts of intensely coloured fruits, for example elderberry and bilberry. The correct colour of wines is, however, ensured by competent blending. It is to be stressed at this point that legislation in the majority of countries does not permit the use of synthetic dyes for the colouring of wines.

A different process is the widely used technique of aromatization of fruit wines, mainly in the form of adding herb or spice extracts (vermouths). Most commonly used are alcoholic extracts obtained by repeated (usually three times) extraction with an alcohol solution at a concentration of 45–70% (v/v). A good base for herb wines are apple wines which are decoloured if necessary prior to addition of herb extracts with the use of activated carbon (Madejska, 1972).

Wines with high sugar and alcohol contents are sometimes aromatized with muscatel essences (Anon., 1960) or of essential oils, so as to comply with local organoleptic preferences (Pijanowski and Wasilewski, 1955).

Wines, including blended and flavoured fruit-wine brands, are subjected to clarification and stabilization processes. Industrial production methods involve most frequently clarification with gelatin or tannin with added gelatin, in doses of up to 10 g/hl of each of these reagents. Clarification is usually carried out with the use of potassium ferrocyanide or of salts of phytic acid (in cases of an excess of iron) with further treatment with pectolytic preparations in the cold, in quantities of 50–300 g/hl, with wine tending towards the precipitation of pectin compounds.

Another phenomenon is likely to occur in wines mellowing for a longer time. This is the production of complexes of iron with organic acids, and particularly with oxalic acid (Krug, 1964a). When wine is clarified with potassium ferrocyanide, it is frequently not possible to remove sufficient quantities of iron. This is so because of the occurrence, noted as early as during the initial tests, of an excess of potasium ferrocyanide along with considerable quantities of iron being left over (iron contained in complex compounds with organic acids is not removable by potassium ferrocyanide). Where iron occurs in complex compounds, and in the presence of oxalic acid, Krug (1964b) recommends precipitation of that acid by addition of calcium carbonate at 50–70 mg Ca/l.

Good results are also obtained by a two-stage clarification. The first stage involves precipitation of iron in the ionic state, followed by the gradual dissociation of complexes in order to remove the released iron (Nilov and Skurychin, 1967). The presence of cyanides in wine is not permissible.

Kljačko *et al.* (1969) report on clarification of wine with bentonite, with the complementary addition of powdered polyacrylamide for accelerating sedimentation of the lees, while Masior *et al.* (1972a) describe attempts at adding bentonite to fruit musts prior to fermentation. Wucherpfennig and Possmann (1972) describe a combined clarification with the use of gelatin and silica gel.

Masior and Czyżycki (1969) discuss the stabilizing of fruit wines by cooling, while ascertaining that, apart from hedge-rose wine, they have not noted the need to apply this kind of treatment to any other type of fruit wines. Small-scale winery plants use traditional clarification agents, such as egg white, albumin, skimmed milk, casein, and the bladder of sturgeon or sheatfish.

Sedimentation of clarification agents is usually followed by drawing wine off from above the lees, combined with filtration

through a layer of kieselguhr, or through cellulose and asbestos filtering plates. A particularly thorough filtration is required following clarification with ferrocyanide. Small-scale winery plants use filtration through an asbestos mass, with an occasional use of bag filters. It is also possible to stabilize wines by pasteurization at a temperature of 65–68°C, with holding times of up to 30 seconds.

3. *Wine Defects and Diseases*

The term 'wine defect' implies changes in the properties thereof (clarity, colour, flavour, aroma) resulting in a deterioration of the quality, and caused as a result of chemical, biochemical or physico-chemical changes. Defects mostly frequently noted in fruit wines are as follows:

(i) Black casse (wine blackening) is caused by the occurrence and precipitation of iron–tannin compounds. The defect is manifested by a loss of glaze, appearance of turbidity, and by the precipitation of a black coloured sediment.

(ii) Opalescent cloud (white casse) occurs as a result of precipitation of ferric phosphate. A specific feature of this defect is the occurrence of a whitish-blue turbidity, followed by precipitation of a whitish-blue sediment.

(iii) Wine browning (oxidation turbidity) is caused by oxidation of tannins and pigments catalysed by oxidases and oxygen contained in the air. The wines tend to brown in contact with the air, become turbid, and the taste and aroma of the wines change. A strong off-taste of 'aeration' becomes discernible.

Defects also arise as a result of turbidity due to pectins or copper (for example CuS, Cu_2S connected with protein), an odour of hydrogen sulphide, and an off-taste of yeasts or of mildew.

Also recognized as wine diseases are abnormal changes caused by growth of micro-organisms, and resulting in a deterioration of the quality of the product. Two basic groups of wine diseases are distinguished, namely those caused by growth of aerobic bacteria, and those caused by growth of anaerobic or relatively anaerobic bacteria. Microbial infection can be manifested in several forms. There may arise a 'coating' on the surface, caused by the propagation of yeasts (*Candida mycoderma, Hansenula* spp., *Pichia* spp. and *Torulopsis* spp). Wine acetation can be attributed to propagation of acetic-acid bacteria including *Acetobacter kutzingianum, Acetobacter xylinum, Acetobacter pasteurianum* and *Acetobacter aceti.* Diseases caused by growth of anaerobes or relatively anaerobic bacteria include mannite fermentation, lactic fermentation, sliming, bittering of the wine and 'mouse' off-taste. Such diseases are caused by complexes of micro-organisms including *Micrococcus acidovorax, Micrococcus variococcus, Bacterium mannitopeum, Bacterium intermedium* and *Bacterium gracile.* One or other disease process develops depending on the composition of the wine, temperature, acid content and on other conditions. Curing methods in use for microbial diseases include, pasteurization, sterile filtration, sulphitation, acidification of wines with an insufficient acid content, and clarification with the use of tannin and gelatin.

F. Filling-up

Filling-up of wine is effected in bottling machines of various types, either by a non-sterile or by a sterile method. Sterile methods include basically two bottling systems, namely hot bottling at a temperature of 50–55°C, and bottling combined with running wine through microbiological filter plates (of type EK).

G. Sparkling and Carbonated Wines

The Soviet Union, the Federal Republic of Germany and other countries are known for production of sparkling fruit wines, made mainly from apples. Mitjukov *et al.* (1963) supply a description of the technology of production of sparkling apple wines as developed by the White Ruthenian Institute of the Food Processing Industry in Minsk (Soviet Union). Apple juice is sweetened prior to fermentation, up to a sugar content of approximately 19% (w/v), and this is followed by fermentation usually for a period of about 14 days. The wine juice thus obtained is sweetened with syrup, and carbonated in an acratophore (pressure tank), with the pressure of carbon dioxide towards the end of fermentation at a value of 4–5 kg/cm^2. On completion of the carbonation process, the wine is cooled to a temperature of 5°C. After 48 hours, the wine is filtered and bottled in an isobaric bottling machine.

An important process in the production of sparkling fruit wines is the selection of a correct breed of yeasts (Mitjukov *et al.*, 1963), while the duration of the mellowing period for the wine seems to have no great impact on the quality of the final product (Jurčenko *et al.*, 1972).

Carbonated fruit wines (mostly made from apples) are manufactured furthermore in many countries. Wines with an alcohol content of 10–12% (v/v) are sweetened with syrup, saturated with carbon dioxide in saturation equipment under a pressure of approximately 6 kg/cm^2, and filled into bottles in isobaric bottling machines (Pijanowski and Wasilewski, 1955).

V. HONEY WINE (MEAD)

A. Definition and Classification

Mead is an alcoholic beverage obtained as a result of fermentation of honey obtained from bee honey by suitable dilution with water or with fruit juice. Meads are divided in Poland into the following classes, depending on the relation by volume of honey to water added: (i) 'póltorak' (poowtorack) which contains half a volume of water per volume unit of honey; (ii) 'dwójniak' (dvooyniack) containing an equal volume of water and honey by volume; (iii) 'trójniak' (truiniack) with a 1 : 2 relation, by volume, of honey and water; and (iv) 'czwórniak' (tschvoorniack) with a 1 : 3 relation, by volume, of honey and water. Certain legislations permit a part of the honey to be replaced by sugar.

A further distinction is made between; natural meads which have no addition of herb and spice ingredients, and no fruit juices; aromatized meads which receive an addition of extracts of herbs or spices; and fruit meads in which some of the water (usually at least 30%) is replaced by fruit juice. Table 7 lists certain basic analytical data covering Polish meads.

Wojcieszak and Witkowski (1953) have published the following chemical composition for Polish 'trójniak' meads: alcohol, 14.23% by volume; total sugars, 110.2 g/l; non-sugar solubles, 37.6 g/l; total

Table 7

Some analytical data for Polish meads
(Polska Norma, PN-64/A-79123. Miody pitne—Honey wines)

Components	Type of mead 'Czwórniak' (1:3)	'Trójniak' (1:2)	'Dwójniak' (1:1)
Alcohol (% by volume)	9–12	more than 12–15	more than 15–18
Total sugars (g/l)	35–90	65–120	175–230
Factors (alcohol x 18 + total sugars)	250 ± 10	333 ± 10	500 ± 10
Non-sugar solubles not less than (g/l)	15	20	25
and for grape- and fruit mead	20	25	30
Acids as malic (g/l)	3.5–7	4–8	5–9
Volatile acids (as acetic acid, not more than, g/l)	1.6	1.6	1.6

acid content, 5.08 g/l as tartaric acid; volatile acidity, 1.09 g/l as acetic acid. Patschky and Schöne (1970) suggest standardizing the components as chlorides, sulphates, phosphates.

B. Honey as a Raw Material

Natural honey is produced by bees out of floral nectar or honey dew. In this connection, a distinction is drawn between three types of honey, namely nectar honey, honeydew honey, and nectar-honeydew honey. A further distinction is drawn among nectar honies, depending on the kind of plant from which the nectar is obtained, and they are thus subdivided into the individual varieties, namely acacia, buckwheat, lime tree, clover, heather, and others differing from one another by organoleptic qualities and by chemical composition.

The average chemical composition of natural honey of various origins is presented in Table 8. Any kind of honey may be used for production of meads. Notwithstanding this fact, highly appreciated are those honies noted for a strong aroma, and obtained from

Table 8

Chemical composition of honey. From Pijanowski *et al.* (1973)

Component (g/100 g)	Average	Variations	Normal
Water	17.7	13.9–21.4	<20
Inverted sugar	72.4	66.4–77.0	>70
Sucrose	2.0	0.2–7.6	<3.0
Other carbohydrates and 'non-sugars'	7.3	2.0–15.0	>2.0
Nitrogenous compounds (N x 6.25)	0.4	0.25–0.64	>0.3
Ash	0.2	0.07–0.75	>0.1
Acids (as millilitres of N base per 100 g)	2.0	0.9–3.3	>1.0

buckwheat, lime trees, heather and of multi-flower combinations. Jojrys (1966) states that the so-called 'express' honey brands, produced in the Soviet Union, are obtained by feeding fruit (containing sugar) or vitamin syrups to bees. This method proves to be highly economical. Meads produced from express-honey brands differ greatly from beverages obtained from natural honey, the former having a delicate flavour with the fragrance of mead, but slightly marked.

C. Technological Processing

1. *Preparation for Fermentation*

A distinction is drawn between unboiled and boiled meads, depending on the procedure used to prepare the mead wort. Wort for unboiled meads is prepared by cold-mixing honey with water. This procedure, despite its many advantages which include preservation of aroma, vitamins and enzymes (Popova, 1961), is not advocated because it is accompanied by a weaker fermentation, a more difficult clarification, and an off-taste of wax and raw honey in the final product. The procedure is recommended for preparing a beverage from bee honey brands of high quality.

Mead boiling, which is widely used on an industrial scale, involves cooking honey diluted with water, with a possible addition of herb and spice ingredients. Boiling results in a complete 'skimming', i.e.

separation of the resulting froth. The boiling procedure favours an accelerated and more correct fermentation (including volatilization of a part of the formic acid), a better clarification (coagulation of proteins), and contributes to a certain degree to an improvement in the flavour of the beverage thus obtained (Majewski, 1959; Morquin, 1962). Aroma losses occur, however, at the same time. As far as production of boiled fruit meads is concerned, this involves addition

Table 9

Some recipes for production of meads. From Ciesielski (1925) and Tokarz (1927)

Type of mead	Ratio of honey to water (by volume)	Spices: Kind	Spices: Amount (per 100 litres of honey wort)	Time of ageing (years)
Bernardyński	1:2	Hop	50 g	1
		Root of violet	20 g	
		Rose attar	2 drops	
Kasztelański	1:0.5	Hop	100 g	5–10
		Vanilla	3 pods	
		Leafs of celery (fresh)	250 g	
Królewski	1:0.5	Hop	350 g	5–10
Litewski	1:0.5	Fruits of juniper	150 g	4–6
	1:1	Flowers of elder	100 g	

of freshly obtained or pasteurized fruit must on completion of boiling and cooling off, in order to avoid a compote type off-flavour. Examples of constituents for making typical meads, selected on the basis of recipes collected and checked by Ciesielski (1925) and Tokarz (1927), are presented in Table 9.

Honey earmarked for obtaining alcohol is added to mead wort at once ('czwórniak', 'trójniak' brands), or in two or three separate portions (for heavier and strong meads). When a part of the honey is replaced by sugar (usually no more than 20%, w/v), the sugar is

added when the wort is prepared and not reserved for later sweetening.

Bee honey has a relatively low content of nitrogenous substances, and this necessitates the addition of nitrogenous nutrients, usually diammonium phosphate in the quantity of 0.3–0.5 g/l. Application of autolysates of wine yeast (in quantities of up to 5 ml/l) as a nitrogenous nutrient greatly accelerates the rate of fermentation, and permits an improvement in fermentation of the product (Masior and Czyżycki, 1965; Wzorek and Chruszczyk, 1972). When wort is prepared by addition of fruit juices with a high content of nitrogenous compounds (from grapes, raspberries, cherries), addition of a nitrogenous nutrient would be to no avail (Popova, 1961). With the low content of organic acids in honey, wort is frequently after-acidified with citric or tartaric acids. The prepared mead wort is inoculated with a yeast starter prepared from highly fermenting wine yeasts, the inoculum usually being 3–10% by volume of the prepared juice.

2. *Fermentation*

The optimum fermentation temperature is 15–25°C (Ciesielski, 1925; Morquin, 1962; Maugenet, 1964), and the duration of the process is up to 6–8 weeks. The brand of bee honey used is of decisive importance for the course of fermentation. Dark-coloured honey of the heather type ferments quicker than light-coloured ones (Morquin, 1962), while worts made from nectar honey derived from fruit-tree flowers ferment more intensely than those from the lime tree and from various grass varieties (Popova, 1961). Racking from above the lees is carried out three weeks after effervescence of the fermentation has ended, whereas the first drawing-off is carried out sooner if the fermentation temperature is higher and the brand of mead is lighter.

3. *Ageing*

Ageing is effected usually in oaken casks at a temperature of 10–15°C (Morquin, 1962). A temperature of 15–30°C is also permissible, but a higher temperature shortens the ageing time, and also leads to loss of volume (Eliasz, 1959).

Raising the ageing temperature to 55°C, with a moderate access of oxygen, allows the period of ageing to be decreased (approximately six weeks at an increased temperature), while an addition of lees of wine yeasts during that process (1.5%) and of tannins (0.4 g/l) results in an improvement of organoleptic qualities (Wzorek and Chruszczyk, 1972; Wzorek and Lisak, 1973). The course of the ageing process depends furthermore on the kind of mead, the variety of bee honey used, the type of tanks, and on the kind of fruit juice added, if any. An addition of fruit juice obtained from bilberries retards the ageing process, while that from raspberries, on the other hand, helps to adjust the organoleptic qualities of the final product (Popova, 1961).

The duration of ageing of the mead increases as the concentration of honey in the wort is increased. The 'trójniak' brand is ripe after one year from completion of fermentation; the 'dwójniak' brands require a period of at least two years, while some of them are aged for up to ten years (Tokarz, 1927).

The time reserved for effecting the ageing process is used also to adjust the chemical composition of the meads. Obtaining a correct total acidity is effected by addition of citric or tartaric acids, with better flavour effects being obtained from the use of citric acid (Maugenet, 1963, 1964). Fortification with rectified spirit is sometimes used in the production of meads with a high alcohol content, although increasing the mead strength by addition of alcohol is permissible in Poland only when the alcohol content is raised above 13% by volume. Sweetening with bee honey to a required degree of sweetness is effected by adding dilute honey in water, made by a cold or a hot process. Sweetening with cold diluted honey permits a more effective preservation of aroma, while at the same time causing an addition to the beverage of proteins which may cause a turbidity and protein precipitation in the form of lees. Only high quality honey, with a strong, appreciated aroma, should be used for sweetening.

Racking is performed periodically throughout the time of ageing, and this is accompanied by measures taken to obtain stability and clarity (pasteurization, clarification by the use of various methods, and filtrations). Filling up is effected into stoneware or glass bottles styled exclusively for this purpose.