Preparation of Banana Vinegar[1]

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A method of preparing banana vinegar is presented. The experiments were not carried beyond the laboratory scale, but it is hoped the results obtained will serve as a nucleus for further work on a semi-commercial scale.

The banana vinegar prepared was of good color and had a pleasing aroma and taste. Several analyses of banana vinegar are given, as well as a comparison of the composition of this vinegar with the composition of other fruit vinegars.

PRACTICALLY any fruit juice capable of fermentation may be utilized for preparing vinegar. Thus, vinegars have been made from oranges,[2] peaches,[3] and watermelons.[4] In the United States, however, by far the greater amount of vinegar is prepared from apples and the word "vinegar" is synonymous with "cider vinegar." When a customer asks for vinegar the dealer always sells him cider vinegar. In fact, the Federal food standards[5] restrict the term "vinegar" to indicate cider vinegar made from the fresh juice of apples. There are no Federal food standards at the present time for vinegars made from such fruits as oranges, peaches, or watermelons.

A search of the literature failed to reveal definite data for the preparation and properties of banana vinegar. The work reported in this communication was undertaken to supply, in part, this information and to indicate a possible means of utilizing bananas not readily marketable because of excessive scarring or overripeness. Unfortunately, circumstances did not permit the work to be carried beyond laboratory-scale production, but it is hoped the present results may at some time serve as a nucleus for further work on a semi-commercial scale.

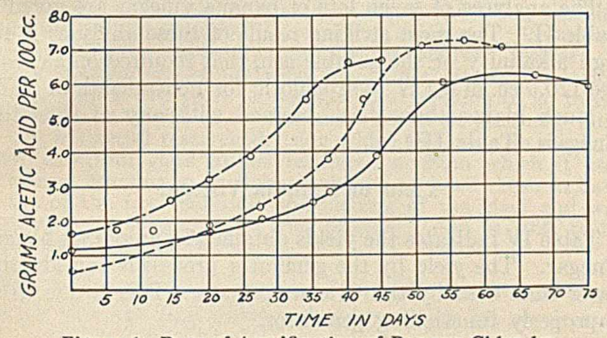

Figure 1—Rate of Acetification of Banana Cider by Orleans Process

Production of Banana Cider

The banana mash, consisting of the pulp and peel of ripe fruit, contained on an average 16 per cent fermentable sugars. Without any further addition of water, a 150-gram portion was pasteurized at 75° C. for 45 minutes, and, after cooling, inoculated with a pure culture of *Saccharomyces ellipsoideus*. The mash was then incubated at 20–23° C. for about 3 days, or until vigorous fermentation had set in. This fermenting mixture, constituting the "starter," was then used to inoculate a larger portion (about 1.5 kg.) of banana mash, pasteurized in the same manner as the starter.

Acetic acid bacteria are surprisingly abundant in the banana mashes, and if not pasteurized as described acetification will proceed faster than alcoholic fermentation, resulting in a low yield. Acetification and fermentation cannot take place simultaneously, for acetic acid retards yeast growth and activity. Cruess[6] claims *S. ellipsoideus* ceases growth and fermentation if the acetic acid concentration exceeds 0.5 per cent.

It was determined that when water was added to the mash the sugars were diluted to such a degree that fermentation became sluggish and *Mycoderma vini*, or "wine flowers," formed, with resulting loss of alcohol and injury to the quality of the product. On the other hand, the mash, without the addition of water, is so viscous that the yeast is not readily disseminated through the mix, and this too tends towards a low yield. The mash, without the addition of water, was found to give the highest yields and the best quality of vinegar.

Incubation of the material was carried out at 20–23° C. from 14 to 20 days. In general, the mash was in vigorous fermentation within 48 hours, and the fermentation was complete in 14 days.

When fermentation had ceased the mixture was filtered through cheesecloth and the residual pulp was pressed in a small fruit press. The milky filtrate was then centrifuged to remove the suspended yeast as much as possible. If an excess of yeast is allowed to remain during subsequent acetification it imparts an inferior aroma and taste to the finished product. The vinegar also becomes unduly dark, tending to assume a muddy appearance.

The yield of fermented juice, called banana cider, amounted to 56 per cent of the weight of the fruit taken, and its alcohol content varied from 6.55 to 10.12 per cent, depending upon the ripeness of the fruit and the efficiency of the fermentation. Table I shows the composition of banana and other fruit ciders.

Table I—Composition of Banana and Other Fruit Ciders

Cider	Specific Gravity	Total Solids	Alcohol (by Volume)	Acetic Acid	Ash	Reducing Sugars
		Grams/ 100 cc.	*Per cent*	*Grams/ 100 cc.*	*Grams/ 100 cc.*	*Grams/ 100 cc.*
Banana	1.0055	3.22	9.44	0.68	..	0.44
Apple[a]	1.0086	3.72	5.19	0.23	0.27	1.69
Grape[a]	0.998	3.25	11.09	0.68[b]	0.28	0.73
Orange[a]	....	3.43	5.75	1.14[c]	0.46	..
Peach[a]	1.0107	4.19	4.07[d]	0.95[e]	..	0.38

[a] After Brooks, "Critical Studies in the Legal Chemistry of Foods" (1927).
[b] As tartaric acid.
[c] As citric acid.
[d] By weight.
[e] As malic acid.

Acetification of Banana Cider

The rate of acetification of an alcoholic solution is proportional to the amount of oxygen in contact with the reacting components. If the surface of the alcoholic solution is increased the rate of acetification is increased. This is the principle of the generator process in which the fermenting

[1] Received August 9, 1928. This is No. 1 of a series of scientific articles to be written by members of the research staff of the United Fruit Company and offered for publication in technical journals.

[2] Poore, J. Ind. Eng. Chem., **12**, 1176 (1920).

[3] Gore, U. S. Dept. Agr., Bur. Chem., *Circ.* **51** (1910).

[4] Brooks, "Critical Studies in the Legal Chemistry of Foods" (1927).

[5] U. S. Dept. Agr., Food Drug Insecticide Adm., S. R. A., F. D., **2** (1927).

[6] "Commercial Fruits and Vegetable Products" (1924).

Table II—Analyses of Banana Vinegar

Vinegar	Amount of Cider Taken	Specific Gravity	Total Acid (as Acetic)	Fixed Acid (as Sulfuric)	Alcohol (by Vol.)	Total Solids	Total Ash	Soluble Ash	Reducing Matter (after Inversion)	Levorotation (200-mm. Tube)	0.1 N Acid to Neutralize Soluble Ash
	Grams		*G./100 cc.*	*G./100 cc.*	*Per cent*	*G./100 cc.*	*G./100 cc.*	*G./100 cc.*	*G./100 cc.*	*° V.*	*Cc.*
GENERATOR PROCESS											
Lot 1[a]	600	1.0160	4.05	0.02	0.20	2.44	0.89	0.81	0.04	−0.3	100.8
Lot 2[b]	1000	1.0181	5.19	0.87	0.13	2.69	1.14	1.04	0.06	−0.2	135.6
ORLEANS PROCESS											
Lot 1	900	1.0017	5.89	0.04	0.46	2.27	0.89	0.82	[c]	−0.4	105.0
Lot 2	776	1.0278	6.52	0.15	0.13	3.96	1.16	1.07	0.10	−0.6	129.5
Lot 3	625	1.0223	7.09	0.18	0.26	2.88	1.12	1.03	0.06	−0.6	122.2
Lot 4	676	1.0151	5.37	0.33	..	2.91	0.93	0.81	[c]	−2.5	118.1
Lot 5	571	1.0190	5.94	0.13	0.13	2.65	1.18	1.10	[c]	..	131.3
Average	...	1.0171	5.72	0.25	0.27	2.82	1.04	0.97	0.04	−0.8	120.3

[a] Aged 1 month. [b] Aged 2 months. [c] Traces.

Table III—Analyses of Banana and Other Fruit Vinegars

Vinegar	Specific Gravity	Acetic Acid	Non-Volatile Acid	Total Solids	Total Ash	Soluble Ash	Reducing Sugars	Levorotation (200-mm. Tube)	0.1 N Acid to Neutralize Soluble Ash
		G./100 cc.	*G./100 cc.*	*G./100 cc.*	*G./100 cc.*	*G./100 cc.*	*G./100 cc.*	*° V.*	*Cc.*
Banana	1.0171	5.72	0.25[a]	2.82	1.04	0.97	...	−0.8	120.3
Cider[b]	1.0177	5.21	0.18[c]	2.40	0.38	0.34	0.47	−1.4	35.0
Watermelon[b]	....	4.60	...	1.01	0.21	...	0.34	...	...
Orange[b]	1.0225	4.91	1.04[d]	4.12	0.57	0.42	0.24	...	54.0
Peach[b]	1.0202	4.81	0.18[e]	3.36	0.49	...	0.65	...	...

[a] As sulfuric acid. [b] After Brooks, "Critical Studies in the Legal Chemistry of Foods" (1927). [c] As lactic acid. [d] As citric acid. [e] As malic acid.

juice is allowed to trickle over some material, such as coke, beechwood or rattan shavings, or pumice, to increase the surface exposed to the air.

In the present work a small generator was constructed from a glass tube, 1 meter long and 5 cm. in diameter. The tube was packed with beechwood shavings, previously boiled in water, dried, and then impregnated with a good strong vinegar. Banana cider, to which had been added about one-third of its volume of strong vinegar, was then allowed to trickle through the column of shavings at the rate of approximately 200 cc. an hour. It required about 50 hours to convert 1 liter of cider to vinegar.

Table IV—Yield of Banana Vinegar

Lot	Based on Weight of Bananas	Based on Weight of Cider Taken
	Per cent	*Per cent*
GENERATOR PROCESS		
1	48.2	73.3
2	49.7	74.4
ORLEANS PROCESS		
3	50.1	97.4
4	52.0	96.4
5	53.6	102.0
6	52.0	85.3
7	51.4	94.8

As it was impossible to regulate the flow of air in this laboratory-type generator, losses were much greater than they would be in a properly constructed generator. Where the supply of air is too great it is possible for all the alcohol entering the generator to be converted into carbon dioxide and water, with the formation of practically no acetic acid.

Freshly prepared vinegar from the laboratory generator was light yellow in color and possessed a harsh flavor and odor. The yield of vinegar (4.5 per cent acid) amounted to 73.8 per cent of the cider taken.

More favorable results were obtained in preparing vinegar by the Orleans process. In this process the fermented juice was placed in flasks of 1 liter capacity, which were filled about three-quarters full and the neck plugged with cotton. About one-fourth of its volume of strong vinegar was then added. This acidified the juice to the point where the growth of *M. vini* was prevented, while it promoted the growth of vinegar bacteria. Usually at the end of 15 days there formed a good film of *M. aceti*, consisting of bacteria cohering by means of a glutinous sheath and forming a zoöglea, which later sank when the flasks were disturbed. Finally a large gelatinous zoögleic mass, "the mother of vinegar," resulted. This "mother" retained considerable vinegar that could only be removed during subsequent clarification by suction. The flasks were incubated at 30° C., and in general acetification was complete at the end of 75 days (Figure 1).

After acetification was complete the vinegar was filtered from the "mother," clarified with 2 per cent kieselguhr, bottled, and then pasteurized for 1 minute at 60° C. Some of the batches were persistently cloudy, despite treatment with kieselguhr.

Banana vinegar obtained by the Orleans process was light amber in color and possessed an agreeable aroma and taste. After standing in bottles for 5 months the color darkened slightly, becoming a very light brown.

The analyses of seven lots of banana vinegar are given in Table II. The most striking result of these analyses is the high alkalinity of the soluble ash, that required on an average 120.3 cc. of 0.1 N hydrochloric for neutralization. This is much higher than that obtained with any of the other vinegars (Table III).

Yield of Banana Vinegar

Table IV indicates the yields obtained in preparing banana vinegar. The yield by the generator process is considerably lower than that by the Orleans process. This is due to an improperly functioning generator.

Polish Rubber Industry Developing

The rubber industry in Poland has made notable progress since the tariff conflict with Germany began in 1925, which led to the restriction of imports of manufactured rubber goods, according to the Department of Commerce. The contingent system on rubber imports was abolished in March, 1928, but a substantial increase in customs duties which accompanied the removal of restrictions left Polish manufacturers with a high degree of protection.

Prior to 1914 only one rubber-manufacturing establishment existed in Poland, the market being supplied mainly by the large Russian plants of Treugolnik and Prowodnik. During the years 1919 to 1923 five new manufacturing plants were opened in Poland. There are now fifteen plants in operation, employing between 6000 and 7000 workers. The production of rubber goods has increased from 450 tons in 1924 to 1900 tons in 1926 and 3000 tons in 1927, while the importation of crude rubber has increased from 725 tons in 1926 to 1753 tons in 1927 and to 1455 in the first half of 1928. Poland's crude rubber purchases are made through Hamburg, London, and Paris. Notwithstanding the steady increase in domestic production, imports of rubber goods into Poland have not yet begun to show any decline.