PRODUCTION AND PROPERTIES OF BIRCH SYRUP
(Betula populifolia)

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Received 30 November 1976

Kok, R., E.R. Norris, and **T. Beveridge**. 1978. Production and properties of birch syrup (*Betula populifolia*). Can. Agric. Eng. 20: 5-9.

Sixteen grey birch trees (*B. populifolia*) were tapped during 1975; fifty were tapped during 1976. Sap was collected daily and boiled to a syrup. The sugar content as well as the volume of the sap produced by each tree was measured every day during the 1976 season. The average seasonal sap production during 1975 was 42.8 *l*/tree; during 1976 it was 27.9 *l*/tree. The average sap sugar content during 1976 was 0.74% (w/v). Trees tapped suffered no apparent ill effects from the tapping. Average syrup *p*H was 4.8. The average syrup (50% by weight sugar) viscosity was 15 centipoise. The syrup ash content increased during the tapping season from 1.22 to 3.3%. The dominant wavelength of the syrup color was 580 nm; its excitation purity was 0.671. The syrup was judged as being acceptable by 59%, of an 82-member taste panel.

INTRODUCTION

Although maple products and their characteristic flavor are today well known, similar products obtainable from birch, walnut, hickory, ash, basswood and butternut trees (Nearing 1950), once produced in quantity, are all but forgotten; syrup, butter and taffy can be manufactured from the saps of these trees as well as from maple sap. The winning of maple sap and its processing have been adequately described in the literature (Nearing 1950; Perrin 1972; Anonymous 1973).

The Canadian per capita annual consumption of maple sugar fell from 1.1 to 0.09 kg/person between 1947 and 1971 (Hassan 1973). Canada's annual export value of maple products rose from 4.3 to 6.4 million dollars between 1949 and 1968 (Daviault 1975); thereafter the annual export value has remained almost constant at 6.5 million dollars during the period 1969 - 1974 (Bolton 1974, 1975). Canadian maple sugar production, consumption and export volumes have steadily declined since 1949. The price of maple sugar has steadily risen since 1949.

Low utilization of equipment (2 or 3 wk/yr) caused by the seasonal nature of maple sugar production is partly responsible for the high cost of maple products. To increase the period of equipment use would require trees yielding sugar-bearing sap at a time other than the productive season of maple trees. This condition is fulfilled by birch trees which start their sap flow during the final stage of the maple sugar season.

The large scale production of birch sap from *Betual pendula* Roth, *B. platyphylla* Sukacz and *B. dahurica* Pall has been reported by Kalinishenko (1974); 28,000 tons of birch sap were produced in the spring of 1972 in the Ukraine. The sugar concentrations of *B. pendula* Roth, *B. platyphylla* and *B. dahurica* Pall saps in the middle of the sap-production season in 1973 were 1.2, 1.9 and 1.8%, respectively.

In Quebec, three species of birch are commonly found: *B. populifolia* (grey birch), *B. papyrifera* (white birch) and *B. alleghaniensis* (yellow birch) (Marie-Victorin 1964; Hosie 1969). For this study, the grey birch was chosen, since it was abundantly available in the immediate vicinity. The grey birch is characteristically one of the first species to reappear after forest destruction and often occurs in dense stands. Grey birch might therefore not only be considered as a sugar-producing plant but simultaneously as a principal component of an energy plantation wherein sugar could be produced as a secondary product.

SAP COLLECTION AND PROCESSING

Methods

Grey birch trees were tapped during the spring of 1975 and 1976 in the Morgan Arboretum of McGill University. During the 1975 season, 16 trees were tapped on 17 March. Trees of circumference greater than 45 cm at 150 cm height above the ground were randomly selected. During the 1976 season, 50 trees of circumference greater than 42 cm were randomly selected and tapped on 8 April. In 1976 the trees were tapped considerably later than in 1975, since sap flow in 1975 started only on 14 April. Tap holes 12 mm in diam and 57 mm deep were drilled in each tree trunk 90 cm above the ground level. Tap holes were drilled at a slight angle facing downward. Spiles were inserted by moderate hammering until a tight fit between the spile and tap hole and the tree bark was obtained.

During both the 1975 and the 1976 seasons, the sap was collected daily when possible (on several occasions seasonal snowstorms prevented collection) at 1400 h.

Daily sap flows were recorded for individual trees.

During the 1975 season, the sap of all trees were combined and kept for subsequent boiling and syrup production. No samples of individual tree saps were kept during this season. In 1976, the sap of each tree was sampled daily at the time of collection and the rest of the sap was combined and kept for boiling.

The solids content of the daily individual tree sap samples was determined by pipetting 10 ml of sap into a drying dish, leaving the dish in a drying oven at 75°C for 24 h and weighing. This method of solids content determination was found to yield solid contents within 0.02% (w/v) when tested with sucrose solutions over the range 0.25 - 1.25 % (w/v). Sucrose has been found to be the major dissolved solid of maple syrup (Nearing 1950).

In the spring of 1975, the birch sap was concentrated to syrup by boiling in an electrically-heated, deep-fat fryer (Torcan Model 210) equipped with a float-operated automatic shut-off switch. Unconcentrated sap was added manually every time the liquid level decrease caused the heating element power to be switched off until 1 *l* of approximately 50% (w/v) sugar was present in the boiler. The syrup sugar concentration was monitored with a refractometer (Pocket Refractometer, Bellingham and Stanly Ltd., London, U.K.) whose readings were converted to the equivalent of % (w/v) sucrose by means of a calibration curve. The electric boiler was found to produce a birch syrup with a slightly scorched flavor although it imparted no such flavor to maple syrup during a pre-production test.

To lower the boiling surface temperature and yet retain a high rate of heat input, a steam-heated boiler was constructed for sap boiling during the 1976 season (Fig. 1). The boiler was completely constructed of 316 stainless steel. It was subdivided by partitions into five sections, each containing a steam coil of ½-inch diam tubing, 75 cm long. The five steam coils were connected in series by bulkhead unions. Incoming steam was saturated and was regulated to remain at 1.7 kPa, thus limiting the maximum possible surface temperature to 131°C. Unconcentrated sap was continuously fed by gravity from a constant head tank to the first compartment. Partially concentrated sap flowed over weirs cut at successively lower heights in the partitions into

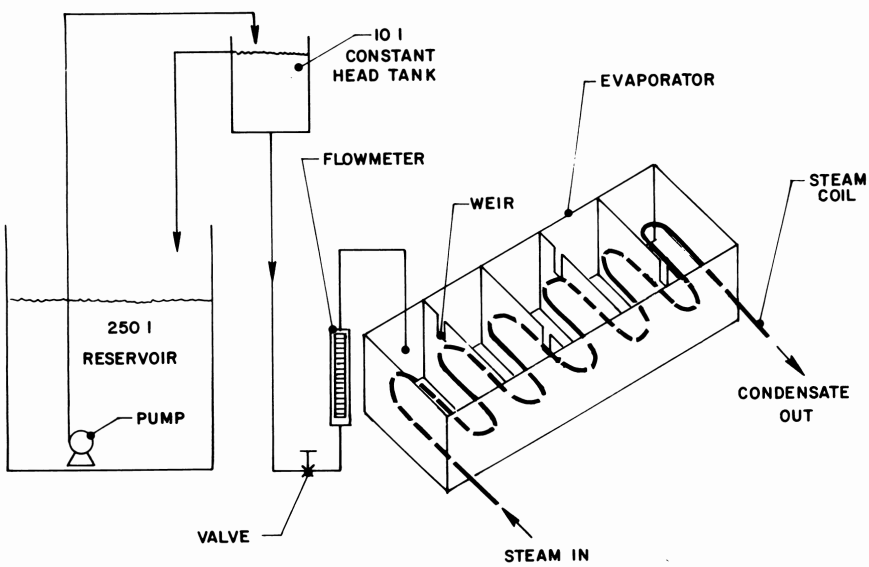

Figure 1. The steam-heated evaporator.

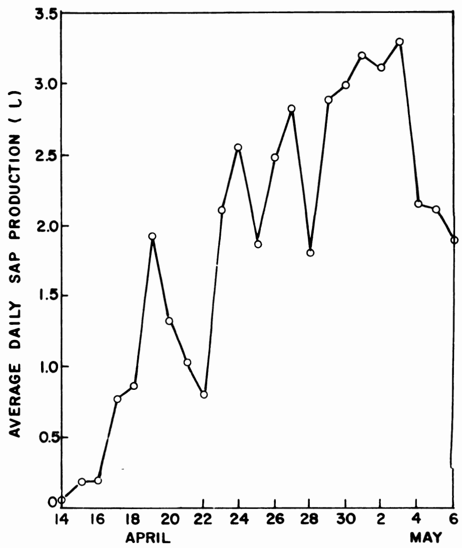

Figure 2. Average daily sap production per tree during the 1975 season.

consecutive boiler compartments. A standpipe in the last compartment permitted continuous operation; the lack of adequate control equipment made the utilization of this feature impossible. The incoming sap flow rate was therefore manually adjusted so that the final compartment would not overflow for up to 6 h of operation. All steam coils were mounted 7.5 cm above the bottom of the boiler to prevent the syrup from becoming excessively concentrated when the incoming sap flow rate became inadequate to utilize the heat supply either as a result of pump failure, line clogging or exhaustion of sap in the reservoir. A sap flow rate of approximately 0.20 *l*/min usually proved adequate. Upon exhaustion of the available sap, partially concentrated syrup from the first four compartments was manually transferred to the last compartment and there concentrated to 50% (w/v) sugar as determined by the refractometer. The syrup was transferred from the boiler to 1-*l* bottles and stored in a refrigerator at 4°C for further analysis. Fourteen batches of syrup were thus produced, the first batch from the saps collected up to and including 14 April, the fourth batch being produced from the combined sap collected on 17 and 18 April and the other batches being produced from the sap collected each day.

Observations during the 1975 Season

The average tree diameter was 17.5 cm (standard deviation (SD) = 2.4 cm). Sap was obtained from the trees between 14 April and 6 May inclusive (23 days). Although by 6 May the trees had not stopped producing sap, leaves started to appear and the sap acquired an unpleasant taste and smell best described as "green." The average daily sap production per tree is illustrated in Fig. 2.

The average total quantity of sap produced per tree during the collection period was 42.8 *l* (SD = 19.0 *l*).

Observations during the 1976 Season

Tree diameters were normally distributed (5% significance, chi-square); the average diameter was 17.4 cm (SD = 2.8 cm).

Sap was obtained from the trees between 8 April and 28 April inclusive (21 days). Not all trees commenced and finished sap production simultaneously; during the 21-day season, the average production period for trees was 16 days. By 28 April, sap flow had decreased significantly (Fig. 3a) and the birch sap had acquired its characteristic unpleasant flavor and odor signalling the end of the collection season. Subsequent to the removal of spiles and buckets from the trees, sap continued to be exuded from the tap holes in some trees for another 3 wk. The average daily sap production per tree is shown in Fig. 3a.

The average total quantity of sap produced per tree during the collection period was 27.9 *l* (SD = 21.0 *l*). The total quantity of sap produced per tree was normally distributed as determined by the chi-square test (5% significance level). The total quantity of sap collected and processed was 1,395 *l*.

The average daily sap dissolved solids contents (henceforth referred to as the sugar content) is shown in Fig. 3b. The average sap sugar content for all trees during the collection season was 0.74% (w/v). The seasonal average sap sugar content for individual trees was normally distributed (sample mean 0.75%; SD = 0.11%) as determined by the chi-square test (5% significance level). The average daily sugar production per tree is shown in Fig. 3c.

The average quantity of sugar produced per tree during the collecton season was 205 g (SD = 158 g). The quantity of sugar produced per tree was normally distributed as determined by the chi-square test 5% significance level). The total quantity of sugar produced during the season was 10.3 kg.

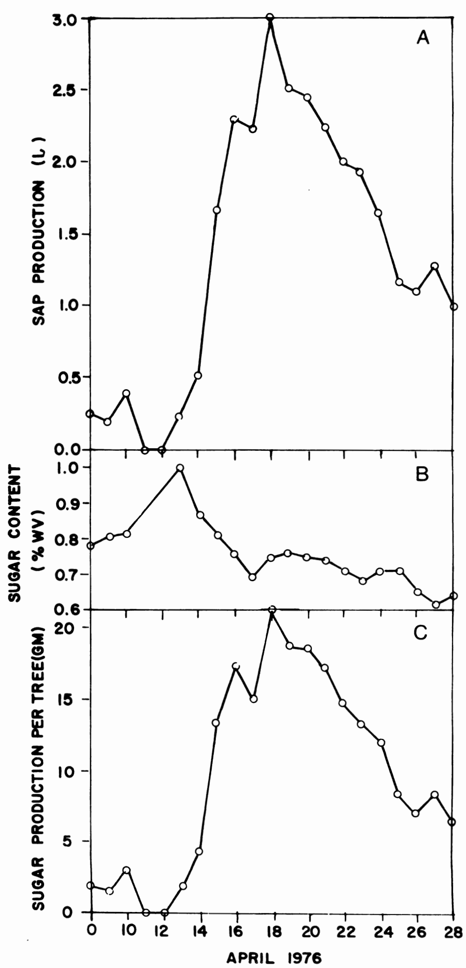

Figure 3. Production characteristics during the 1976 season: (A) average daily sap production per tree; (B) average daily sugar content of sap; (C) average daily sugar production per tree.

Tap holes in trees tapped during the 1975 season were partly covered with scar tissue 1 yr later, although the holes were still readily visible. During neither the 1975 nor the 1976 season was any gross difference observed between the development of tapped and untapped trees; leaf development of tapped trees did not appear to be affected by tapping.

DISCUSSION

The typical daily sap production patterns shown in Figs. 2 and 3a, illustrating an initial small sap flow, inhibited by 1 or 2 days of frost, followed by the main production period during which daily sap flow initially increased rapidly and then decreased gradually is also described by Kalinichenko (1974).

Although the collection season length in 1976 was not considerably shorter than during 1975 (23 days vs. 21 days), the total quantity of sap produced per tree during 1975 was substantially larger than during 1976 (42.8 *l* vs. 27.9 *l*). The unusually early and sudden spring of 1976 which also substantially reduced the local maple sugar harvest is judged to be at least partially responsible for the decrease in birch sap yield.

Since the trees were randomly selected from a natural population, members were included in the samples which would ordinarily not be tapped commercially. Several of the trees were in poor health as evidenced by extensive rot on the trunk and later in the season an almost complete lack of leaf development. The average seasonal tree sap yield could probably be substantially increased if the trees were selected according to criteria such as lack of apparent rot, lack of extensive bark damage and general appearance.

In a commercial enterprise it would be desirable to select trees according to their anticipated sugar production capability as well as to determine the minimal size of tree which could be profitably tapped. It was therefore attempted to find sets of parameters which were significantly related. The results of this analysis are outlined below.

The correlation coefficient between the tree diameter and the total sap volume produced per tree was 0.36 (significant at 1% level) in 1976; in 1975, no significant correlation coefficients between these variables could be found. In 1976, the correlation coefficient between the tree diameter and the total sugar produced per tree was 0.35 (significant at 5% level); during 1975, individual tree sugar production was not measured.

No significant correlation coefficients (5% level) were found between the average sap sugar concentration of individual trees and (a) tree diameter and (b) total sap production of individual trees. No significant correlation coefficient (5% level) was found either between the daily total sap production and the daily average sap sugar concentration for all trees combined.

When the trees were subdivided into three groups according to their total seasonal sap production during 1976 (group 1: 19 trees, less than 17.4 *l*, group 2: 15 trees, between 17.4 and 38.4 *l*, group 3: 16 trees, greater than 38.4 *l*), no significant correlation coefficients (5% level) were found between the daily sap production and the daily sugar concentration of two randomly selected trees in each group. Sap sugar concentration was independent of all other parameters measured and hence would be impossible to predict before tapping.

When the trees tapped during 1976 were divided into two groups based on their existing either as single trees or as members of a clump of two or more trees sharing a common root system (28 single trees, 22 growing in clumps), a two-tailed t-test (5% significance) revealed no significant difference between the average seasonal sap production of members of the two groups.

The correlation coefficients between the daily average sap production per tree and the mean of the maximum and minimum temperatures observed each day (temperature data obtained from the Montreal International Airport, approximately 15 km from the collection site) were 0.59 and 0.87, repectively (both signficant at 1% level), during 1975 and 1976. Daily sap flow was strongly dependent on the average daily temperature.

The 0.74% (w/v) seasonal average sap sugar content found for *B. populifolia* in this study was considerably lower than the sugar content of birch sap found by Kalinichenko (1974) for *B. pendula* Roth (1.2%), *B. platophylla* Sukacz (1.9%) and *B. dahurica* Pall (1.8%). The economic feasibility of recovering sugar from such a dilute solution by evaporation might be questionable. Other methods of concentrating, such as reverse osmosis, used as a preliminary concentrating step prior to boiling, might be applicable to decrease processing costs (Timbers et al. 1974).

SYRUP PROPERTIES

Fourteen batches of birch syrup of slightly different concentrations were available for analysis. The concentrations of these syrups were adjusted to 50% (wt) sugar content by the addition of distilled water. The sugar content was verified by a dry weight determination as follows: approximately 0.2 g of syrup was transferred to an aluminum weighing dish, 10 ml distilled water was added, the dish was shaken to mix the syrup and the water and to spread the solution evenly throughout the dish, the dish was placed in an oven at 100°C and its weight determined after 24 h. The above method yielded a solids content within 0.5% (wt) sucrose solution; when dilution water was not added, results were erratic, since syrup droplets became imprisoned within a hard shell of dried syrup solids. Commercial pure maple syrup (initially 69%, wt) was similarly adjusted to 50% (wt) concentration. Sixteen syrups (standardized maple syrup, 14 birch syrups and 50% (wt) sucrose solution) were analyzed as described below.

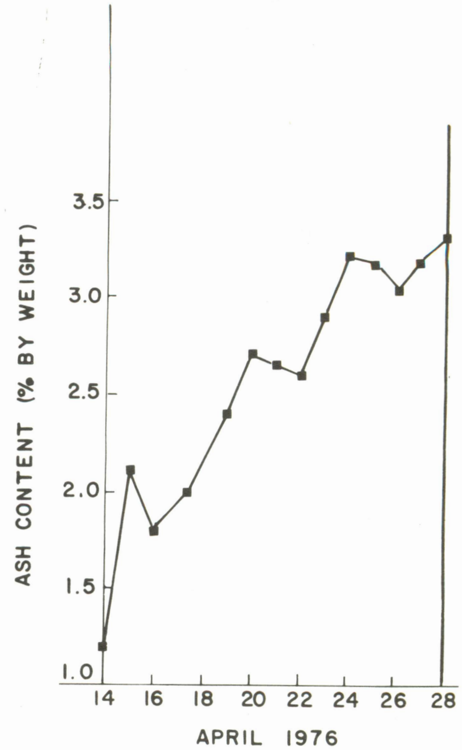

Figure 4. Ash content of birch syrups.

pH of Syrups

At 21°C the *p*H of the 50% sucrose solution and the standardized maple syrup were, respectively, 6.8 and 5.7; the average *p*H of the birch syrups was 4.8 (SD = 0.2).

Viscosity

At 21°C, the viscosities of the 50% sucrose solution and the standardized maple syrup were, respectively, 16 and 13 centipoise; the average viscosity of the birch syrups was 15 centipoise (SD = 3). A Brookfield Model LVT (No. 1 spindle, 60 rpm) viscometer was used.

Ash Content

The ash content of the syrups was determined by the following procedure: 2-4 g of syrup was placed in an aluminum weighing dish and the material was dried in an oven at 100°C for 24 h. The dish was then placed in a muffle furnace at 550°C for ½h. The ash weights obtained were corrected for the average weight loss (2 mg) of an empty aluminum dish subjected to the same heating procedure as outlined above. The ash content of the maple syrup was 0.4% (wt); the average birch syrup ash content was 2.6% (wt). The gradual increase in birch syrup ash content during the 1976 season is shown in Fig. 4.

TABLE I. COMPARISON OF COLOR VARIABLES FOR MAPLE AND BIRCH SYRUP
Values reported for birch syrups are averages for 14 syrups; standard deviations are shown in brackets. Variable names are standard CIE nomenclature.

	Maple syrup	Birch syrup
Overall transmittance *Y*	96	50 (11)
Chromaticity *X*	0.321	0.451 (0.035)
Coefficients *Y*	0.331	0.436 (0.014)
Dominant wavelength (nm)	570	580 (3)
Excitation purity	0.077	0.671 (0.123)

TABLE II. RESPONSE FREQUENCIES TO BIRCH SYRUP COLOR, ODOR AND TASTE QUESTIONS AND LIKING FOR MAPLE SYRUP

	Birch syrup color	Birch syrup color	Birch syrup color	Maple syrup color
Like extremely	0.06	0.06	0.01	0.42
Like very much	0.12	0.14	0.13	0.36
Like moderately	0.26	0.22	0.20	0.11
Like slightly	0.14	0.15	0.14	0.06
Neither like or dislike	0.20	0.16	0.04	0.01
Dislike slightly	0.14	0.18	0.13	0.01
Dislike moderately	0.07	0.04	0.10	0.00
Dislike very much	0.01	0.01	0.12	0.00
Dislike extremely	0.00	0.04	0.13	0.03

Color

Standardized maple and birch syrup were diluted with 50% (wt) sucrose solution in the ratio: 1 volume syrup, 19 volumes sucrose solution. Using 50% (wt) sucrose solution as reference, the transmittance of the diluted syrups was measured in the range 400-750 nm (Beckman Model 25 Spectrophotometer, 1-cm cells). CIE tristimulus *X*, *Y*, *Z* values and trichromatic coefficients *x*, *y*, *z* were calculated by the weighted ordinate method for standard illuminant C using a wavelength interval of 10 nm (Mackinney and Little 1962; Frances and Clydesdale 1975). From these values the dominant wavelength and excitation purity were determined by the method described by Mackinney and Little (1962). The values of the relevant variables are recorded in Table I.

Direct comparison of the experimental color values with commercial standards for maple syrup (Nearing 1950) was not possible since all syrups were diluted with 50% (wt) sucrose solution. The extent of dilution was necessary to obtain birch syrup transmittances within the capabilities of the spectrophotometer used. The birch syrup was considerably darker than the maple syrup; the dominant wavelengths for the two syrups were similar.

Sensory Evaluation

Samples of 5 ml each of 50% (wt) birch syrup were distributed to 82 students who were asked to independently rate on a standard nine-point hedonic scale (Larmond 1970) the color, odor and taste of birch syrup. In separate questions they were asked to place, from memory, maple syrup on the same hedonic scale and to state whether the birch syrup was acceptable or not. No attempt was made to directly compare maple and birch syrups.

The panel consisted of 65 males and 17 females; judges' ages were predominantly between 18 and 25. Response frequencies are shown in Table II and 59% of the judges thought the birch syrup acceptable, while 41% thought it unacceptable. Although the sample of judges was by no means representative of the population as a whole, it is evident from Table II that birch syrup was considerably less acceptable in the form presented than was maple syrup as evaluated by recall. Noteworthy in Table II is the relatively large proportion of dislike responses for birch syrup taste. This may be attributable to flavors described variously as "molasses," "burnt," or "licorice" by individuals in the panels giving a negative response.

CONCLUSIONS

The average sugar content of the sap obtained from *B. populifolia* was 0.74% (w/v); during 1975, 42.8 *l* of sap was produced per tree whereas during 1976, 27.9 *l* of sap was produced per tree. Significant correlation coefficients were obtained during both seasons between the average daily temperature and daily sap production. Seasonal sap and sugar production of individual trees were directly related to tree diameter in 1976. No obvious detrimental effect on the trees was observed as a result of tapping. Average syrup (50%, wt) *p*H was 4.8 and average viscosity was 15 cp. The syrup ash content increased from 1.2% (wt) to 3.3% (wt) between the beginning and the end of the season during 1976. The dominant wavelength of the birch syrup diluted 20 times with 50% (wt) sucrose solution was 580 nm; its excitation purity was 0.671. The birch syrup was judged as being acceptable by 59% of the members of an 82-member panel.

Further efforts will be directed towards the production of syrups from other species of birch and other trees as well as improving the flavor of birch syrup by the use of alternate processing methods.

ACKNOWLEDGMENT

The authors wish to express gratitude to Agriculture Canada for their financial support.

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