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Published in:
Lebensmittel-Wissenschaft und-Technologie

DOI:
10.1006/fstl.2001.0869

2002

Research Note

Characterization of Apples and Apple Cider Produced by a Guelph Area Orchard

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(Received August 8, 2001; accepted December 5, 2001)

Thermal stability of food-borne pathogens in apple cider is influenced by the composition of the product. As a preliminary step to determining the effect of pasteurization of apple cider on survival of E. coli *O157:H7, a study was carried out to characterize apples and unpasteurized apple cider produced by a guelph area orchard. Samples of commercial unpasteurized cider and the constituent apples were collected over 13 wk from August to November 1998, and unpasteurized laboratory cider was made from the individual apple varieties. pH, titratable acidity (TA), turbidity, total microbial counts, total solids and °brix for filtered and unfiltered samples were measured. The maximum, minimum, and average values for all unpasteurized commercial cider samples were found to be: pH, 3.71, 3.17, and 3.43; TA, 93.47, 49.46, and 69.95 mL of 0.1 N NaOH/100 mL; total solids, 13.21, 10.93, and 11.90%; °brix, 13.01, 11.17, and 12.02; turbidity, 238.1, 145.1, and 204.9 NTU; and total plate count, 4.91, 2.61, 3.75 log cfu·mL^{-1}. There were no significnat differences ($P > 0.05$) between filtered and unfiltered samples. In addition, in commercial unpasteurized cider, there were no significant differences ($P > 0.05$) with respect to any of the factors with time of processing. The composition of the unpasteurized laboratory cider made form individual apple varieties was dependent on the variety, but was generally within the ranges from published literature values. Mclntosh apples showed a significant ($P \leq 0.05$) decrease in TA with time of harvest. The results suggest that it is necessary to take the composition of commercial apple cider into account when developing thermal inactivation models for food-borne pathogens.*

Keywords: apple; cider; microbial population; pH; titratable acidity; total solids; turbidity; °brix

Introduction

In the U.S., the FDA is considering several new safety standards to apply to fresh juices including mandatory pasteurization of all apple cider. In Canada, Health Canada is also taking similar approach. Pasteurization requirements depend on the physical and chemical properties of the cider, thus will differ for the various species of apples used for cider production. Apple cider is made from different types of apples depending on the season (Tressler and Joslyn, 1954). Therefore, the physical and chemical properties of cider also varies according to the type of apples used. The thermal resistance of microorganisms is strongly influenced by the nature of the heating menstruum. Factors such as pH, type of acid, sugar content and solids level can have significant impact on the heat sensitivity of bacteria targeted for destruction by pasteurization process (Ray, 1996). For this reason, the cider produced from different apples has to be evaluated for their properties to establish the range of these variations. It is essential to know what the end product will be, and its degree of variation in order to design a safe and efficient pasteurization process. In addition, the initial microbial population determines the degree of thermal processing required to reduce these organisms to a specific level. For this reason, the microbial population of the cider samples was also determined.

Developing a pasteurization process for a single type of cider may not reflect industry's needs as fluctuating product characteristics may result in the process providing inadequate microbial destruction. The objective of this study is to measure the microbiologically significant properties of cider and apples over the harvesting season. The goal of this work is to consider the degree of variability of cider produced in a Guelph area orchard in order to provide data to develop a safe pasteurization process and develop models to predict the properties of cider based on the properties of apples used.

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Contribution No. S072 from the Food Research Program.

0023-6438/02/$35.00
doi:10.1006/fstl.890

Materials and Methods

Collection of commercial apple cider

A 4 L sample of unpasteurized apple cider was collected each week for 13 wk from August to November, 1998 from a local cider producer. This sample had been pressed that same day and no preservatives were added. To simulate the settling step in the cider production process, the 4 L sample was placed in a refrigerator over night to settle and samples were taken from the top phase.

Preparation of laboratory apple cider

When commercial cider samples were collected, a representative sample of the apples from which the cider was made was also obtained, and the relative weight ratios of the different constituent varieties were recorded. For the preparation of unpasteurized laboratory cider, apples were cut into cubes, and the seeds stem were removed. The apples were then placed (approx. 300 g) in a household blender (Waring Blender, Model 700b, Waring products Co., CT, U.S.A.) and diced until the resulting pieces were approximately 2–5 mm in diameter. The resulting pulp was placed in a double layer of cheese cloth (EKO Bakers Secret, Niagara Falls, ON, U.S.A.) inside a buchner funnel (approximately 20 mL at a time). A pestle was used to press the liquid out of the pulp. The remainder of the liquid was recovered by gathering the cloth around the pulp and twisting to force out the remaining liquid. The waste was removed from the cheese cloth and the process was repeated for the remaining pulp. The resulting liquid was then divided into two volumes, one was filtered and the other remained unfiltered.

Filtration of cider and apple Samples

Two 10 mL samples were initially clarified by centrifugation for 30 min at 2,000 rpm to remove larger debris. The top phase was then filtered using a syringe to press the liquid through a 4.5 μm filter (Arco Disc, HPLC type, Gelman, GHP, An Arbor, Ml, U.S.A.).

Physical, chemical, and microbial analysis of apple ciders

Total solids measurement: oven method. The total solids of the filtered and unfiltered commercial and laboratory ciders were determined using a drying oven (AOAC, 1984). A crucible was pre-dried in the oven for approximately 1 h, allowed to cool in a desiccator and weighed empty. Approximately 1.4 g of sample was added and the weight was taken to nearest mg. Three replicates were made unless otherwise noted. The crucibles were placed in a drying oven at 80 °C and atmospheric pressure. They were weighed after 24 h by transferring the crucibles to the desiccator, and then making the measurement after cooling. The drying time was determined from the first few trials. It was found that the samples were fully dried after 24 h as successive weighing after 24 h were within 3 mg.

Measurement of pH and titratable acidity. The pH and titratable acidity of unfiltered unpasteurized commercial and laboratory cider samples were determined using a pH meter with a glass electrode (Accumet, model AP50, Fisher Scientific, Pittsburgh, PA, U.S.A.). Titratable acidity (TA) was determined according to the AOAC (1984) procedure. Cider samples were placed in a beaker with a magnetic stir bar and the pH electrode was immersed in the sample. While stirring moderately, 0.1 N NaOH solution was added using a 25 mL burette. The NaOH solution was added rapidly until the meter read pH 6. It was then added slowly until pH 7 was reached. The titration was finished by adding NaOH solution at four drops at a time until pH 7.9 was achieved, after which a single drop was added till a time until pH 8.10, then continued until four drops beyond the pH 8.10 reading. The volume of 0.1 N NaOH was recorded to the nearest 0.05 mL (one drop) and interpolated, when necessary, to determine the volume at pH 8.10. The TA was reported as mL of 0.1 N NaOH per 100 mL of sample.

When cider acidity data from published studies were being compared to the present study, values reported as percent total acid (as malic acid) were converted to TA using a formula weight of 134 for malic acid, and the relationship: 1 N malic acid $\equiv$ 2 N NaOH.

°Brix measurement. The °brix of both the filtered and nonfiltered cider and apple samples was measured using a refractometer (Lecia Abbe Mark II, Model 10480, Buffalo, NY, U.S.A.). A small sample volume (approximately 0.1 mL) was applied using an eye dropper, and a temperature-compensated reading was recorded. The measurements were taken at room temperature (20–22 °C).

Turbidity measurement. Turbidity of the unfiltered cider samples was determined using a digital direct reading turbidimeter (Orbeco-Hellige, model 965-10A, Farmingdale, NY, U.S.A.). In order to bring the turbidity to the instrument's more reliable measurement range, samples were diluted to 50%. The turbidity measurement was reported in nephelometric turbidity units (NTU).

Total plate counts. The microbial population of the apple cider was determined using a total plate count method. Samples stored at 4 °C overnight before plating. Dilutions (10^0, 10^1, 10^2, 10^3) were made using 0.1% peptone water, and spread plated on tryptic soy agar (TSA; Difco Laboratories, Detroit, MI, U.S.A.) plates. Duplicate plates were made for each dilution. The plates were incubated at 30 °C and enumerated after 32–72 h of incubation. The plate counts were reported as log colony forming units (cfu) per mL.

Statistical analyses

For the commercial apple cider, mean values of pH, TA, total solids and brix of cider were compared by the

Table 1 Properties of a series of apple ciders collected from a Guelph are orchard

Property	Aug 25	Sept 2	Sept 9	Sept 16	Sept 23	Sept 30	Oct 7	Oct 14	Oct 21	Oct 28	Nov 5	Nov 11	Nov 18
Apples used	25% GD 50%TR 25%VB	75% LB 25%TR	50%LB 50%M	50%LB 50%M	50%LB 50%M	100%M	100%M	50%EP 25%RD 25%MS	25%M 75%S	100%SN	100%SP	50%SN 50%GD	50%SN 50%SP
pH	3.48±0.00 $n=3$	3.41±0.00 $n=3$	3.27±0.00 $n=3$	3.17±0.01 $n=3$	3.25±0.02 $n=3$	3.19±0.00 $n=3$	3.29±0.00 $n=3$	3.71±0.00 $n=3$	3.40±0.01 $n=3$	3.47±0.00 $n=3$	3.67±0.01 $n=3$	3.60±0.00 $n=3$	3.67±0.00 $n=3$
Titratable acidity	70.56 $n=1$	70.68 $n=1$	87.40 $n=1$	93.47 $n=1$	79.91±4.5 $n=3$	82.44±0.64 $n=3$	77.72±0.15 $n=3$	51.35±0.07 $n=3$	70.86±0.56 $n=3$	67.34±3.42 $n=3$	49.80±0.28 $n=3$	58.41±0.09 $n=3$	49.46±0.08 $n=3$
Total solids (%)													
Filtered	10.94±0.00	11.89±0.08	11.53±0.07	11.70±0.07	12.99±0.31	11.75±0.01	11.62±0.01	12.56±0.07	12.16±0.02	11.54±0.07	10.88±0.06	12.38±0.02	11.33±0.04
Unfiltered	10.93±0.07 $n=2$	11.92±0.03 $n=2$	11.48±0.07 $n=2$	11.83±0.04 $n=2$	13.21±0.19 $n=2$	11.97±0.06 $n=3$	11.88±0.01 $n=3$	12.55±0.54 $n=3$	11.76±0.20 $n=3$	11.20±0.06 $n=3$	10.87±0.83 $n=3$	12.13±0.04 $n=3$	11.07±0.02 $n=3$
°*Brix*													
Filtered	11.17±0.09	11.80±0.10	11.13±0.03	11.70±0.10	13.07±0.07	12.07±0.03	11.5±0.00	12.57±0.03	11.37±0.08	11.73±0.07	11.23±0.07	12.17±0.03	11.87±0.03
Unfiltered	11.17±0.09 $n=3$	11.67±0.03 $n=3$	11.27±0.07 $n=3$	11.97±0.03 $n=3$	13.01±0.00 $n=3$	12.20±0.00 $n=3$	12.2±0.00 $n=3$	12.73±0.03 $n=3$	11.30±0.00 $n=3$	11.50±0.06 $n=3$	11.45±0.07 $n=3$	12.27±0.03 $n=3$	11.87±0.03 $n=3$
Turbidity (NTU) (at a 50% dilution)	N/A	N/A	196.0±0.58 $n=3$	198.3±15.77 $n=9$	232.8± 3.46 $n=9$	176.6±0.97 $n=9$	246.7±4.46 $n=9$	179.3±1.80 $n=9$	145.1±5.50 $n=9$	N/A	N/A	N/A	238.1±0.6 $n=9$
Total plate count (log cfu/mL)	3.53; 3.45	3.52; 3.20	3.56; 3.64	4.22; 4.12	4.10; 4.08	4.28; 4.30	4.03; 4.09	3.23; 3.26	3.51; 3.65	4.91; 4.89	3.64; 3.69	3.77; 3.65	2.61; 2.65

Notes: GD = Golden Delicious, TR = Tydeman's Red, VB = Vista Bella, LB = Lobo, M = Mcintosh, EP = Empire, RD = Red Delicious, MS = Mutsu, SP = Spartan, SN = Spencer. Values shown are MEAN ± SEM (Standard error of the mean) except plate count which is the raw duplicate values, n = number of data points/replicates. Titratable acidity was expressed as mL 0.1 N NaOH/100 mL).

"*t*-test" using Prism TM software (GraphPad Software, San Diego, CA, U.S.A.). Mean values of total solids and brix obtained from filtered and unfiltered samples of a given day were also compared. For the laboratory apple cider, PROC GLM in SAS (SAS, 1990) was used to compute the analysis of variance for pH and total solids. Pairwise difference between seasons were also computed using least significant difference (LSD) multiple comparisons test (SAS, 1990). Since there was only one observation for TA at each time, the analysis of variance could not be used; therefore, PROC REG in SAS (SAS, 1990) was used to filt a linear regression line for two varieties, Lobo and McIntosh.

Results

A range of unpasteurized commercial apple ciders from a local processor were analysed over the cider season (August–November, 1998), and the results are shown in **Table 1**. The maximum, minimum, and average values were found to be: pH, 3.71, 3.17, and 3.43; TA, 93.47, 49.46, and 69.95 mL of 0.1 N NaOH/100 mL; total solids, 13.21, 10.93, and 11.90%; °brix, 13.01, 11.17, and 12.02; turbidity, 238.1, 145.1, and 204.9 NTU; and total plate count, 4.91, 2.61, 3.75 log cfu/mL. The approximate varietal composition was also recorded. This was found to vary quite markedly; often, a single variety was used, but as many as three varieties were used in some batches of cider. It was determined that there were no significant ($P>0.05$) differences between filtered and unfiltered unpasteurized commercial cider. In addition, there were no significant ($P>0.05$) linear trends with time for any of the analysed factors (**Table 1**).

The composition of various apple varieties obtained from a local Guelph orchard was also tested (**Tables 2a–c**). Data were available for two varieties (Lobo and Macintosh; **Table 2a**) over a period of at least 4 wk, thus it was possible to search for trends with time of harvest. TA was the only factor which appeared to change consistently with time. For Lobo apples, TA decreased with time of harvest in a distinct but nonsignificant manner ($R^2=0.529$; $P=0.273$). Similarly, the TA of McIntosh apples also decreased with time; in this case the change was statistically significant ($R^2=0.714$; $P=0.034$). For both varieties an concomitant but nonsignificant ($P>0.05$) increase in pH was noted over time. There was also a slight but nonsignificant ($P>0.05$) decrease in TS with time of harvest.

Limited data were available for other apple varieties (**Tables 2b** and **c**). Four varieties (Golden Delicious, Tydeman's Red, Spartan, and Spencer) were obtained at two harvest dates, while the other four varieties (Vista Bella, Empire, Mutsu, and Red Delicious) were available only on a single harvest date. Thus, it was not possible to make useful statistical comparisons in many cases. TA and pH for all varieties were generally within the range found for unpasteurized commercial ciders (**Table 1**), with the exception of Golden Delicious and Red Delicious which had lower TA and higher pH than the commercial ciders. Brix was also higher in Spencer

Table 2a Properties of a series of Lobo and Mcintosh apples collected from a Guelph area orchard

	LOBO				McINTOSH				
Property	Sept 2	Sept 9	Sept 16	Sept 23	Sept 9	Sept 16	Sept 23	Sept 30	Oct 7	Oct 21
pH	3.17±0.00	3.21±0.00	3.43±0.00	3.38±0.00	3.24±0.00	3.17±0.00	3.16±0.00	3.18±0.00	3.12±0.00	3.41±0.00
	$n=1$	$n=2$	$n=3$	$n=3$	$n=2$	$n=2$	$n=3$	$n=3$	$n=3$	$n=3$
Titratable acidity[a]	108.02	107.38	77.84	90.60	101.07	108.85	85.242	76.48	88.77	66.86
	$n=1$	$n=1$	$n=1$	$n=1$	$n=1$	$n=1$	$n=1$	$n=1$	$n=1$	$n=1$
Total solids (%)										
Filtered	12.48±0.06	12.57±0.05	12.30±0.11	12.06±0.15	12.46±0.06	12.32±0.04	11.95±0.10	9.87±0.14	12.30±0.03	11.33±0.03
Unfiltered	13.45±0.01	13.04±0.03	12.42±0.04	11.43±0.24	12.45±0.06	12.46±0.01	12.10±0.17	9.85±0.16	13.08±0.02	11.30±0.16
	$n=2$	$n=2$	$n=2$	$n=3$	$n=2$	$n=2$	$n=3$	$n=3$	$n=3$	$n=3$
°Brix										
Filtered	12.80±0.00	12.60±0.00	12.23±0.03	12.10±0.00	12.50±0.00	12.80±0.00	12.17±0.07	10.37±0.07	12.43±0.03	12.03±0.03
Unfiltered	12.83±0.03	12.53±0.03	11.70±0.00	12.63±0.07	12.50±0.00	12.10±0.00	12.30±0.00	10.47±0.03	13.40±0.00	11.90±0.06
	$n=3$	$n=3$	$n=3$	$n=3$	$n=3$	$n=3$	$n=3$	$n=3$	$n=3$	$n=3$

Note: Values shown are MEAN±SEM (standard error of the mean), n = number of data points/replicates.
[a]Only one data point was obtained due to small sample volume.

Table 2b Properties of a series of apples collected from a Guelph area orchard

	Golden Delicious		Tydeman's Red		Vista Bella	Empire	Mutsu	Red Delicious
Property	Aug 25	Nov11	Aug 25	Sept 2	Aug 25	Oct 14	Oct 14	Oct 14
pH $n=3$	3.99±0.00	3.78±0.00	3.33±0.00	3.32±0.00	3.40±0.00	3.49±0.00	3.53±0.00	3.93±0.00
Titratable acidity[a] $n=1$	34.87	33.40	90.23	55.57	87.82	53.56	65.90	36.04
Total solids (%)								
Filtered	13.77±0.38	14.50±0.06	11.21±0.02	10.42±0.01	12.21±0.13	12.23±0.07	12.87±0.03	12.43±0.03
Unfiltered	13.72±0.10	11.41±0.01	11.61±0.07	10.66±0.33	12.55±0.02	12.30±0.00	12.40±0.00	12.63±0.03
	$n=2$	$n=3$	$n=2$	$n=2$	$n=2$	$n=3$	$n=3$	$n=3$
°*Brix*								
Filtered	13.03±0.03	14.40±0.06	10.97±0.03	10.37±0.07	12.17±0.03	12.16±0.23	11.66±0.06	12.01±0.04
Unfiltered $n=3$	13.13±0.03	11.43±0.03	11.2±0.00	10.27±0.03	12.03±0.03	12.05±0.32	11.32±0.14	12.20±0.06

Note: Values shown are MEAN±SEM (standard error of the mean), n = number of data points/replicates.
[a]Only one data point was obtained due to small sample volume.

Table 2c Properties of a series of apples collected from a Guelph area orchard

	Spartan		Spencer	
Property	Oct 21	Nov 5	Oct 28	Nov 11
pH $n=3$	3.71±0.00	3.64±0.00	3.51±0.01	3.65±0.00
Titratable acidity[a] $n=1$	33.97	48.85	83.37	56.91
Total solids (%)				
Filtered	10.62±0.14	16.28±0.05	17.12±0.08	13.80±0.07
Unfiltered	10.61±0.12	12.92±0.14	16.22±0.16	11.32±0.13
	$n=3$	$n=3$	$n=3$	$n=3$
°*Brix*				
Filtered	11.38±0.09	16.20±0.06	16.83±0.03	14.07±0.03
Unfiltered $n=3$	11.30±0.00	13.03±0.09	16.78±0.08	11.30±0.06

Note: Values shown are MEAN±SEM (standard error of the mean), n = number of data points/replicates.
[a]Only one data point was obtained due to small sample volume.

Table 3 Comparison apple juice data from published values (average±standard deviation)

State/Prov	NY[a] ($n=18$)	PA[a] ($n=12$)	NE McIntosh[b]	BC McIntosh[b]	Commercial cider[c]
pH	3.42±0.14	3.75±0.30	3.5	3.35	3.43±0.05
Titratable acidity	87.61±25.37	55.37±26.86	71.64	80.59	69.95±3.99
°Brix	12.02±0.94	13.11±1.28	11.5	12.7	12.02±0.22

[a]Lee and Mattick (1988).
[b]Tressler and Joslyn (1954).
[c]From Table 1.

and Spartan apples than was found with the commercial cider.

Limited data are available from other published studies for comparison (**Table 3**). Lee and Mattick (1988) reported on the composition of apple juice manufactured in a number of states in the U.S.A.; two of these (New York, composed of a mixture of Baldwin, Cortland, Ida Red, Macintosh, Rhode Island Greening, and Twenty Ounce, and Pennsylvania, composed of a mixture of Golden Delicious, Red Delicious, Jonathan, and Stayman) were selected for comparison. The pH ranges of ciders from the present study were very close to those reported for the New York juice, while they were slighly lower compared to the Pennsylvania juice. Similarly, the brix and TA found in the present study were comparable to both U.S. juices.

In another reported study (Tressler and Joslyn, 1954), the composition of individual apple varieties grown either in New England (NE) or British Columbia (BC) were examined. The McIntosh variety was selected in both cases for comparison with the present study (**Table 3**). The pH, TA and brix values for the commercial cider

samples were within the range of values reported for the McIntosh varieties from the two areas, while the vales found for the local McIntosh apples were generally comparable.

Discussion

Apple cider in Ontario is normally produced in small on-farm processing operations. There are approximately 150 cider processing sites in Ontario, and some of the larger ones can produce volumes of up to 5000 L/wk. Few cider processors pasteurize their product. Cider is composed of different blends of varieties, depending on availability. Mclntosh often comprise up to 100% of any given batch since they are generally more available, and provide a higher level of juice.

In the present study, commercial unpasteurized cider varied markedly in composition and varieties used over the experimental period. This led to variation in the range of factors examined (pH, TA, TS, and °brix), which was generally found to be within the ranges reported by other workers (Tressler and Joslyn, 1954; Lee and Mattick, 1988). Surprisingly, there were no significant linear trends with time of apple harvest. This may have been due in part to the use of random blends of apple varieties in the manufacture of the commercial ciders over the harvest period. Previous work has shown that, with simulated cider, factors such as pH, TA and brix can influence the thermal stability of *Escherichia coli* O157:H7 (Li Wan Po *et al*., 2002). The ranges of factors used in that study were based on the present survey of commercial cider composition. A wide range of factors were found for the various apple varieties, and while clear differences were noted, there were insufficient data to show any significant trends. Some varieties such as Golden Delicious and Red Delicious might be expected to have a greater impact on composition. Thus, it will be necessary to take cider composition into account when developing thermal inactivation models for food-borne pathogens.

Acknowledgements

The authors thank Mr John Glasgow of Long Lane Orchards, Campbellville, Ontario for his help and for providing cider and apple samples, and Aileen Hawke for her assistance with the total plate count.

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