

Physical-Chemical Parameters of Latvian Apple Juices and Their Suitability for Cider Production

Rita Riekstina-Dolge, Zanda Kruma, Daina Karklina, Fredijs Dimins

Abstract—Apple juice is the main raw material for cider production. In this study apple juices obtained from 14 dessert and crab variety apples grown in Latvia were investigated. For all samples soluble solids, titratable acidity, pH and sugar content were determined. Crab apples produce more dry matter, total sugar and acid content compared to the dessert apples but it depends on the apple variety. Total sugar content of crab apple juices was 1.3 to 1.8 times larger than in dessert apple juices. Titratable acidity of dessert apple juices is in the range of 4.1 g L^{-1} to 10.83 g L^{-1} and in crab apple juices titratable acidity is from 7.87 g L^{-1} to 19.6 g L^{-1} . Fructose was detected as the main sugar whereas glucose level varied depending on the variety. The highest titratable acidity and content of sugars was detected in ‘Cornelia’ apples juice.

Keywords—Apple juice, hierarchical cluster analysis, sugars, titratable acidity.

I. INTRODUCTION

APPLES are rich in pectin, dietary fibers, organic acids, mineral substances and vitamin C [1], [2]. Sugar content in apples is dependent upon apple variety [3] and on changes during maturation, as well as on relative sugar accumulation [4]. According to Kupferman [4] sugars level depends on the relationship between the tree leaves and fruits: increasing leaf size and optimizing photosynthesis throughout the tree crown will increase fruit sugar accumulation [5]. The sugar content of apples may vary depending on several conditions: apples grown in sunlight have greater total sugar content than fruit grown in the shadowy parts of a tree, and the differences at various harvesting periods can be statistically significant [6]. A variety properties usually has much more significant impact on sugar content than storage time [7]. The main monosaccharides in apples are hexoses – glucose and fructose. Their concentration can vary depending on the degree of apple maturity [8]. Fructose, glucose, and sucrose are the main fruit sugars which characterize a fruit’s quality and market value [9], [10]. Apples contain more fructose than glucose (as opposed to peaches, plums and apricots, where glucose levels are higher than fructose) [11], [12], usually surpassing glucose content by 2-3 times [13]. Fructose is sweeter than other carbohydrates and it usually comes in a cyclic d-fructofuranose form.

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Wu et al. [14] compared eight commercially grown apple varieties and concluded that the fructose ratio (average 53.9 g L^{-1}) was greater than glucose content (average 33.8 g L^{-1}), and sucrose content averaged 24.0 g L^{-1} .

It is important to define the relationship between the fructose and glucose in apple juice, because this can affect the sensory characteristics of the finished product. During the fermentation process, yeast give preference to glucose, and fructose is used secondarily [15], [16]. As a result, there is an observable increase of fructose excess in the fermenting mash, which can increase the risk of microbial instability in the finished product. In addition, fructose is approximately two times sweeter than glucose, which creates an undesirable sweetness in dry wines [17]. From oligosaccharides in apples are presented sucrose and traces of other sugars, for example, xylose [18]. Comparing technically ready apples with fully mature apples, sucrose levels increases [3], but the level and changes of sucrose is also influenced by variety. For his part, Roth [7] in his research has discovered that, where sucrose levels decrease in apples during storage, glucose levels increase, as low molecular weight apple sugars have a tendency to grow during storage, as the result of starch hydrolysis [13]. Xylose belongs to a class of non-fermenting sugars which can be fermented only with a few specific micro-organisms, but in some fermentation processes lactic acid, acetic acid, citric acid, succinic acid and other carboxylic acids, as well as a bit of alcohol could be produced.

Apples’ naturally occurring sugar alcohol sorbitol which fluctuates by about 0.2%, is a key tool in wine testing methods, as it indicates the presence of apple or some other seed or stone fruit additive in the wine [8].

From polysaccharides in fruits small amounts of starch and fibres are present. Starch is in apples in small quantities, and its concentration decreases during ripening [18], because starch converts to sugars, and it is an indicator of fruit ripeness, as opposed to bananas, where starch in ripe fruit is 3% more than in unripe fruit.

Total soluble solids content, 98.8% of which are sugars [19], is another standard index of fruit ripeness. The soluble solids content of the fruit may be affected by various factors, such as water, nutrients, weather conditions and even condition of the tree.

Organic acids are an important component of the fruit flavors, which together with soluble sugars and flavoring substances creates the organoleptic quality associated with fresh apples [20]. Fruit grown in regions with a cool climate is usually more acidic than fruit grown in warmer regions [21]. Organic acids in fruit reach the maximum level when fruit

reaches its optimum degree of ripeness. The dominant organic acids in apples and apple juice are malic and citric acids [22] as well as small quantities of tartaric, succinic etc. acid [14]. Malic acid is the main organic acid present in apples (0.3–1.0%), and its content closely correlates with titratable acidity [23]. Malic acid quantity may be affected by variety, the degree of ripeness, environmental conditions, as well as growth and storage times [24].

The aim of the current study was to determine the composition of apple juices from several varieties produced in Latvia and evaluate their suitability for cider production.

II. MATERIALS AND METHODS

Experiments were carried out at the Faculty of Food Technology, Latvia University of Agriculture in 2012.

A. Raw Materials

Apples grown at the Latvian State Institute and A/S Pūre Horticultural Research Centre were used in the experiments. Apples were harvested and stored for 1–2 weeks at $+3\pm 1^\circ\text{C}$ with relative ambient humidity of 90–95%.

In the present study 14 varieties of apples were used:

- dessert apple varieties ('Auksis', 'Antonovka', 'Merry Gold', 'LietuvasPepins', 'Remo', 'DI-93-4-14' (Nr.14);
- crab apple varieties ('Kerr', 'Kuku', 'Quaker Beauty', 'Riku', 'Hyslop', 'Cornelie', 'Ruti', 'K-8/9-24').

Apple juice was obtained with a hydraulic press – Basket press 60K (Vorán Maschinen GmbH, Austria). For stabilization of juice 'Tannisol' (Enartis, Italy) was added. Tannisol capsules consist of potassium metabisulphite (added amount to juice – $9.5\text{g } 100\text{ L}^{-1}$), ascorbic acid ($0.3\text{g } 100\text{ L}^{-1}$) and tannin ($0.2\text{g } 100\text{ L}^{-1}$).

B. Determination of Soluble Solids, Titratable Acidity and Sugar Content

Soluble solids and titratable acidity were determined according to standards LVS EN 12143:2001 and LVS EN 12147:2001. Titratable acidity is the total acid content of apple juice, expressed as malic acid content. The concentration of glucose, fructose, and sucrose in juice was determined by HPLC Shimadzu LC – 20.

C. Statistical Analysis

The results were processed by mathematical and statistical methods. Data were subjected to one-way analysis of variance (ANOVA) by Microsoft Office Excel 2007, significance was defined at $p < 0.05$. The data obtained from the analysis of the apple juices were analyzed by hierarchical cluster analysis. The method used was linkage between-groups. The distances between samples were calculated using square Euclidean distances. As pre-treatment of data was carried out transforming values of variables (average zero and standard deviation 1) called Z scores. The dendrogram similarity scales generated by the SPSS program range from zero (greater similarity) to 25 (lower similarity). The similarities between the analyzed samples were presented in the dendrograms.

III. RESULTS AND DISCUSSION

A. Soluble Solids, Titratable Acidity and pH of Apple Juices

The essential ingredient of cider is apple juice, so it is important to assess the physical–chemical parameters of the apple juice. Content of soluble solids of apple juice vary from 105.01 to 175.78g L^{-1} and it is affected also by the organic acid composition of apple juice and the results showed a moderately close correlation ($r=0.50$) between the soluble solids and the titratable acidity of apple juice (Table I). Titratable acidity of dessert fruit apple juice is 4.1g L^{-1} (variety 'Auksis') to 10.83g L^{-1} (variety 'Antonovka'). In Eisele et al. [25] study about 175 varieties apple juices titratable acidity was within the range of 2.3 to 18.2g L^{-1} . In crab apples, titratable acidity was on average 10.8g L^{-1} , with the highest concentration in 'Cornelia' apples juice (19.6g L^{-1}) and the lowest in 'Kuku' apples juice (7.7g L^{-1}). The total acidity content of cider varieties juice obtained from apples grown in the Czech Republic was from 3.25 to 5.11g L^{-1} [26], which is lower than the results observed in the experiment. Finland's crab's variety 'Ranetka Purpurovaja' had a titratable acid content of 28.28g L^{-1} in apple juice, and soluble solids content was 148.24g L^{-1} [27], which is similar to a 'Cornelia' variety parameters. pH is the negative logarithm of ion activity which characterizes acidity and alkalinity and there is not certain trend that pH correlates with titratable acidity. Our study showed a moderately close negative correlation between juice pH and titratable acidity ($r=-0.50$). Apple juice pH level is within the range of 2.96 (variety 'Cornelia') to 3.39 . For cider fermentation according to Lea [8] a pH level of 3.3 – 3.8 is recommended. Juice from 'Cornelia' has the lowest pH. It is recommended that low-pH juices could be mixed with other juices until the desired pH level is reached.

TABLE I
SOLUBLE SOLIDS, TITRATABLE ACIDITY AND pH OF APPLE JUICES

Apple variety	Soluble solids in juice, g L^{-1}	Titratable acidity in juice, g L^{-1}	pH in juice
'Auksis'	105.01 ± 0.08	4.10 ± 0.15	3.37 ± 0.01
'LietuvasPepiņš'	122.52 ± 0.06	8.66 ± 0.11	3.11 ± 0.01
'Remo'	126.03 ± 0.00	10.34 ± 0.16	3.05 ± 0.01
'DI-93-4-14'	116.82 ± 0.17	8.10 ± 0.27	3.17 ± 0.01
'Antonovka'	109.67 ± 0.00	10.73 ± 0.10	3.05 ± 0.04
'Merry Gold'	109.34 ± 0.06	5.10 ± 0.20	3.05 ± 0.01
'Quaker Beauty'	160.31 ± 0.10	7.03 ± 0.16	3.34 ± 0.01
'Kerr'	122.83 ± 0.10	6.73 ± 0.19	3.28 ± 0.01
'Cornelie'	175.78 ± 0.01	19.60 ± 1.16	2.96 ± 0.01
'Riku'	162.33 ± 0.08	12.78 ± 0.25	3.17 ± 0.02
'Kuku'	174.31 ± 0.10	7.87 ± 0.13	3.38 ± 0.01
'Hyslop'	145.51 ± 0.06	10.27 ± 0.56	3.29 ± 0.02
'Ruti'	160.36 ± 0.10	10.56 ± 0.24	3.39 ± 0.01
'K-8/9-24'	120.32 ± 0.06	10.47 ± 0.26	3.23 ± 0.01

B. Sugars in Apple Juices

Soluble solids in the juice consist mostly of sugars. Total sugar and glucose content of apple juice from dessert fruit varieties differs significantly ($p < 0.05$) (Table II). The results showed a strong positive correlation ($r=0.87$) between soluble solids and total sugar content, and between the soluble solids

content and the glucose content ($r=0.81$). Predominant sugars in apples are fructose and glucose (average 40%) [28]. Total sugar content of apple juice from dessert varieties ranges from 57.14g L⁻¹ ('Antonovka') to 124.47g L⁻¹ ('DI-93-4-14'). Total sugar content of crab apple juice ranges from 103.70g L⁻¹ ('Kerr') to 163.08g L⁻¹ ('Ruti'), which is 1.3-1.8 times larger than in apple juice from dessert fruit varieties. Glucose content of dessert fruit apple juice averages 11.03g L⁻¹, with the lowest count in the 'Antonovka' variety juice (12.92g L⁻¹) and the highest in a hybrid 'DI-93-4-14' juice (18.94g L⁻¹). The glucose content of crab apple varieties averages 33.38g L⁻¹, which is 3 times larger than in dessert fruit apples and the

highest content in 'Cornelie' apple juice (60.24g L⁻¹) was detected. The Feliciano [29] et al. study of Portuguese apple glucose content was on average 15.1g L⁻¹ in traditional apples and 1.44 in exotic apples. In a study of dessert fruit Latvian apples, glucose content ranged from 12.0g L⁻¹ to 24.0g L⁻¹ [30]. In the juices of dessert fruit apples, fructose content ranged from 41.65g L⁻¹ ('Remo') to 59.55g L⁻¹ ('Auksis'), and in crab apple juice it ranged from 23.50g L⁻¹ ('Hyslop') to 66.91g L⁻¹ ('Riku'). The fructose and glucose ratio in dessert fruit apples is on average 4.4 while the crab apple fructose/glucose ratio is on average 1.6. To achieve the desired degree of sweetness in a beverage, the blending of juices can be carried.

TABLE II
CONTENT OF SUGARS IN APPLE JUICES

Apple variety	Fructose, g L ⁻¹	Glucose, g L ⁻¹	Fructose –glucose ratio	Sucrose, g L ⁻¹	Total sugar content, g L ⁻¹
'Auksis'	59.55±2.29	14.60±0.43	4.1	25.56±0.73	99.70
'Lietuvas Pepinš'	52.08±1.93	10.99±0.52	4.7	41.54±1.54	104.61
'Remo'	41.65±1.54	12.27±0.44	3.4	53.32±1.57	107.24
'DI-93-4-14'	58.89±2.68	18.94±0.59	3.1	46.64±1.50	124.47
'Antonovka'	53.23±2.22	12.92±0.10	4.5	22.00±0.09	87.14
'Merry Gold'	50.49±2.29	7.47±0.27	6.8	33.58±1.34	91.54
'Quaker Beauty'	44.32±1.48	25.34±0.77	1.7	69.27±3.30	138.92
'Kerr'	50.23±1.93	23.93±0.96	2.1	29.54±0.95	103.70
'Cornelie'	66.03±2.20	60.24±2.51	1.1	26.40±0.80	152.67
'Riku'	66.91±2.31	59.64±2.59	1.1	24.23±1.21	150.77
'Kuku'	47.16±1.81	31.24±0.89	1.5	84.68±3.14	163.08
'Hyslop'	23.50±0.84	27.38±1.24	0.9	80.09±2.67	130.97
'Ruti'	52.24±2.27	39.28±1.12	1.3	46.70±2.03	138.22
'K-8/9-24'	36.88±1.12	12.20±0.44	3.0	51.55±1.84	100.63

Sucrose content is significantly higher in the juice of 'Kuku' (84.09g L⁻¹), 'Hyslop' (80.09g L⁻¹) and 'Quaker Beauty' (69.27g L⁻¹) variety apples. Sucrose content of dessert varieties apple juices is from 2 to 53.3g L⁻¹. Scientists have found a similar quantity of sucrose in the juice of apples from Poland – 42.4g L⁻¹ [3].

Soluble solids, titratable acidity, pH and sugar content in To perform cluster analysis of the key indicators of apple juice, namely the soluble solids content, titratable acidity and total sugar content, apple juices were grouped together by similar indicators in 2 clusters (Fig. 1).

The first cluster included all dessert apple variety juices and the juices of crab apple varieties 'Kerr' and 'K-8/9-24'. The first cluster samples have the lowest dry matter content, total sugar content and titratable acidity (Table III).

TABLE III
AVERAGE VALUES OF TITRATABLE ACIDITY, SOLUBLE SOLIDS AND SUGAR CONTENT IN CLUSTERS

Cluster number	Soluble solids in juice, g L ⁻¹	Titratable acidity, g L ⁻¹	Total sugar content, g L ⁻¹
1 (n=8*)	116.57±7.67	8.21±2.47	102.38±11.20
2 (n=6)	163.10±11.06	11.36±4.53	145.77±11.79
Total (n=14)	136.51±25.49	9.56±3.71	120.98±24.85

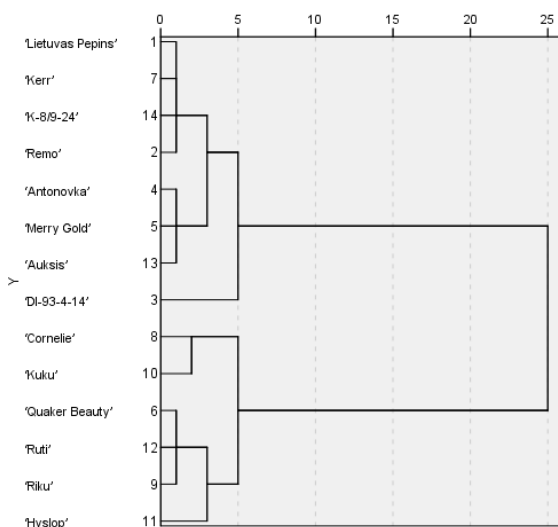


Fig. 1 Dendrogram obtained by hierarchical cluster analysis using mean soluble solid content, titratable acidity and total sugar content

In the second cluster, crab apple juices were included with respectively higher soluble solids content, total titratable acidity, and sugar indicators. To achieve the desired quality of cider, the blending of juices can be applied.

IV. CONCLUSION

Soluble solids, titratable acidity, pH and sugar content in apple juices from 14 apple varieties differed. For some dessert and crab variety apple juices has similar physical – chemical parameters, but in general, crab apples was more soluble solids, total sugars and higher titratable acidity to the dessert apples. Fructose was detected as main sugar whereas glucose level varied depending on the variety. The highest titratable acidity and content of sugars was detected in ‘Cornelia’ apples juice.

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