

TRENDS IN THE BIOCHEMISTRY OF CERTAIN CHERRY VARIETIES UNDER THE INFLUENCE OF CLIMATE CHANGE

Anton Sotirov 

Received on April 27, 2026

Presented by H. Najdenski, Member of BAS, on June 30, 2026

Abstract

The aim of the study is to determine the trends of change of biochemical indicators of some of the most popular cherry varieties as a result of climate change. This study examines the impact of climate change on the biochemical characteristics of cherry fruits in the Kyustendil valley (Bulgaria) for the period 2020–2025. Two standard cherry varieties were analysed – Bing and Van. The biochemical indicators studied are total dissolved sugars, electrical conductivity, acidity, redox potential, total dissolved solids, and salt. The results show a distinct trend towards an increase in temperatures and a decrease in precipitation, leading to decrease in sugars and acidity and increase of electroconductivity and total dissolved solids for both studied varieties, as well as a disruption of the salt balance in drier years as the salt content is higher than the dissolved solids. The low electrical conductivity is due to the higher content of organic acids, which are part of the total dissolved solids (TDS), or to the presence of impurities, sediments, gases, and other degradation products resulting from anhydrous and wax appearance temperatures, suggesting that the cherry varieties studied are beginning to reach their maximum tolerance to heat and drought. Differences between the two varieties underline genotype-specific responses, with Bing showing stronger negative trends in sugar accumulation, while Van exhibited relatively greater biochemical stability. Correlation and cluster analyses confirmed the relationship between climatic parameters and biochemical indicators, emphasizing that temperature and water availability (water/salt balance) are key drivers of changes in fruit biochemical profiles.

Key words: climate change, cherries, biochemistry, agroclimatic stress, sustainable agriculture

Introduction. In order to trace the changes in the biochemistry of cherries, harvests of six consecutive years of two “standard” cherry varieties were studied: Van and Bing. Over a six-year period, cherries supplied for direct consumption or to food processing and canning companies in Kyustendil were studied.

Cherry is a species highly sensitive to sudden climatic changes, especially in valleys characterized by sudden changes in weather conditions such as sharp cold snaps in spring. The Kyustendil field has such features [1,2]. DROGOUDI et al. [3] investigated how climate change affects the phenology and yield of cherries – data that are indirectly related to biochemical and physiological responses of plants. EL KETTABI et al. [4] published data on the biochemical composition of sweet cherries and their relationship to climatic factors. Research indicates that climatic conditions influence biochemical traits in sweet cherries such as phenolic compounds, sugars, and antioxidant capacity. Fruit quality traits and environmental influence were described by [5]. A research in Romania found strong correlations between environmental factors and fruit quality variables such as soluble sugars, which are biochemical traits influenced by climate conditions like water availability and temperature.

Information about the influence of climatic conditions on sour cherry phenology was provided by PERJU et al. [6]. They studied the impact of climate variability on the development of several sour cherry cultivars, including phenological and growth stages that can indirectly influence biochemical trait expression. Another group of studies, although not directly related to the biochemical alterations caused by climate change, provides a good description of the biochemical composition of cherries. UPADYSHEVA et al. [8] published data on the biochemical composition of cherry (*Prunus avium* L.) fruits as a function of scion-rootstock combinations, determining key biochemical parameters, including soluble solids, total sugars, ascorbic acid concentration, and antioxidant activity.

Lumivero’s 2025 [9] release of XLSTAT introduces a no-code statistical software solution integrated into Microsoft Excel, offering a streamlined user interface and AI-powered tools presented statistical data processing using the computer program XLSTAT. SANTOLARIA et al. [10] monitored the climate change adaptation in sweet cherry cultivation. Studies on chilling requirements and phenological adaptation under warming conditions illustrate how climate change influences flowering timing, dormancy release, and associated biochemical processes, which affect fruit set and quality. SOTIROV [11] wrote about statistical approach and using of cluster analyses in his study of the cherry juices.

VASILISHINA [12] found that, with regard to the chemical composition of cherry fruits formed during ripening, the content of soluble substances and sugars in the fruits increased significantly as the sum of effective temperatures rose,

with almost no precipitation (12.8 mm). The same conditions help to reduce the acidity of the fruit and increased sugar-acid index to 10. The content of tannins and colouring substances in the fruits of sour cherry is consistently high regardless of weather conditions (1.00–1.04%). A strong correlation was found between the hydrothermal coefficient and the content of dry soluble substances, and a regression equation was derived.

Physio-biochemical responses of cherry leaves to temperature stress was described by VOSNJAK et al. [13]. Experiments on sweet cherries show that low temperature exposure alters photosynthesis, stomatal conductance, and metabolic responses (e.g., sugars, phenolics), which are biochemical markers relevant in cold stress and potentially in shifting climate scenarios. WENDEN et al. [14] studied general trends in plant phenology in the context of global climate change; although they do not specifically address cherries, the long-term data show that warming leads to phenological changes (bud break, flowering) that subsequently influence biochemical processes during development and ripening.

The aim of the study is to identify trends in changes in the biochemical parameters of some of the most popular cherry varieties as a result of climate change.

Materials and methods. The study covers the period from January 01, 2020 to October 01, 2025. The climate component includes measurements of precipitation and temperatures daily, monthly, and annually over a 3–6-year period.

Digital instruments – a potentiometer, combined with conductometer were used for the determination of active acidity (pH), electrical conductivity EC ($\mu\text{S}/\text{cm}$), total dissolved solids TDS (ppm), total salt content (ppm,%), specific gravity (S.G.) – oxygen-redox potential-ORP (Eh, mV) and temperature (t, °C) with automatic correction of values, according to the temperature of the liquid and Bluetooth transfer of the data received.

Digital and analogue refractometers with a range of 0–80% ($\pm 0.2\%$) and 0–90% ($\pm 0.2\%$) with divisions of 0.5% were used for determination of dissolved sugars in the fruits. The instruments measure dissolved sugars by Brix in %, used in food industry (resp. g/100 ml (Si)).

The meteorological data was obtained from an automated meteorological system Meteobot®Pro, with software of the same name for Android and Windows systems. The system has a Wi-Fi internet connection with mobile devices. Data from a standard, non-automated weather station were also used.

The juice for determining the yield was produced by the cold pressing method, using a regular press with pressure 2.5 atm. at temperature 20–22 °C in normal air environment. For the purposes of the task cherry varieties Van and Bing, distributed by the local producers around the Kyustendil valley, and Institute of Agriculture-Kyustendil, Agricultural Academy-Sofia, Bulgaria were used.

Incoming control tests were carried out on all batches received in two processing enterprises in the region from the specified cherry varieties, and the sampling

was carried out in accordance with Bulgarian State Standard BDS 3485-83. Each sample taken reflects and characterises the entire batch. The sample size is determined according to BDS 11052-82. According to HACCP, all documents such as analysis certificates, protocols, etc. are kept by the laboratory technician. Studies were also carried out on the same varieties of cherries grown by the Institute of Agriculture-Kyustendil, Bulgaria.

Statistical processing was done by the method described by Lumivero (2025) [9] with a computer program Excell and XLSTAT PRO (2025) [15].

FAO (Food and Agriculture Organization, 2022) [16], is a document on adaptation strategies in fruit and horticulture to climate change. Adaptation to climate change in fruit growing is the creation of an integrated strategy, including the selection of sustainable varieties, improved agrotechnical practices and effective management of resources such as water and soil. FAO develops methods to guide national data producers in generating and using sound statistics.

All measurements have been carried out in accordance with the requirements of Directive 2001/112/EC on fruit juices and related products and references to other regulations.

Results and discussion. The study was performed according to the “Bulgarian ordinance on the requirements for fruit juices and some similar products intended for human consumption”, Bulgarian State Gazette No 100, 2013 [17].

Trends of the precipitations and temperatures are shown in Fig. 1. It is obvious that the temperatures increases, but the amount of precipitation decreases.

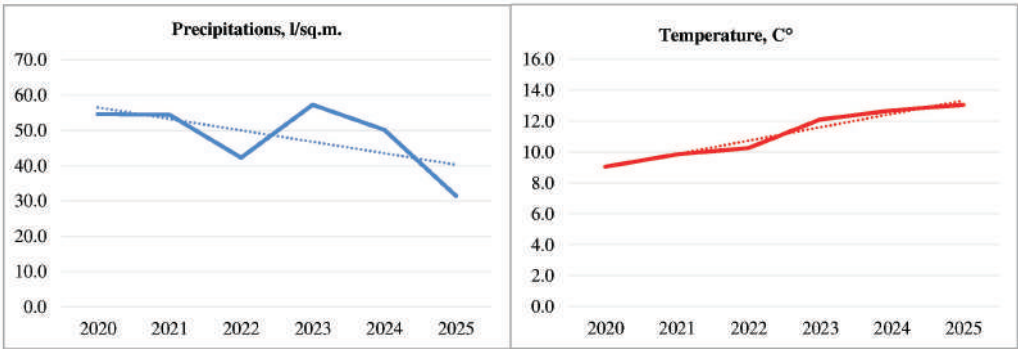


Fig. 1. Trends of average annual temperatures and precipitations for the studied period 2020–2025

Figure 2 provides data about the measurement of the biochemical indices of the cherry variety Bing, used for food industry in the region. Figure 3 provides the same data for the variety Van.

The quantity of the total dissolved sugars of variety Bing decreases every year, except 2021, but the trend is for decreasing of their amount (Fig. 2A). The trend of acidity pH also decreases, because of year 2025, caused by the very warm

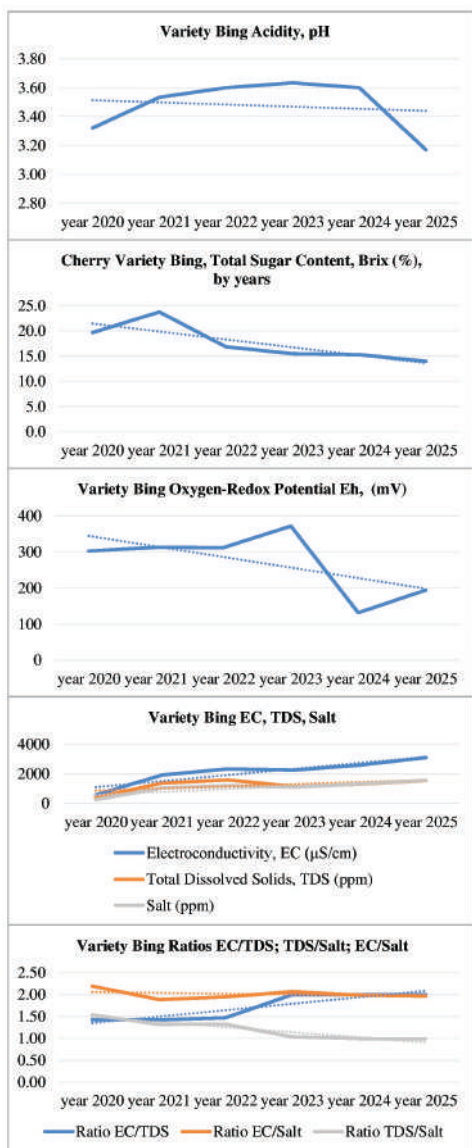


Fig. 2. Trends in the biochemistry of sweet cherry variety Bing for the studied period 2020–2025: A – Trend of total dissolved sugars by Brix, (%); B – Trend of acidity (pH); C – Trend of Oxygen-Redox Potential Eh; D – Trends of Electroconductivity (μS/cm), Total Dissolved Solids (TDS, ppm) and Mineral Salts (Salt, ppm); E – Trends of ratios EC/TDS, TDS/Salt, EC/Salt

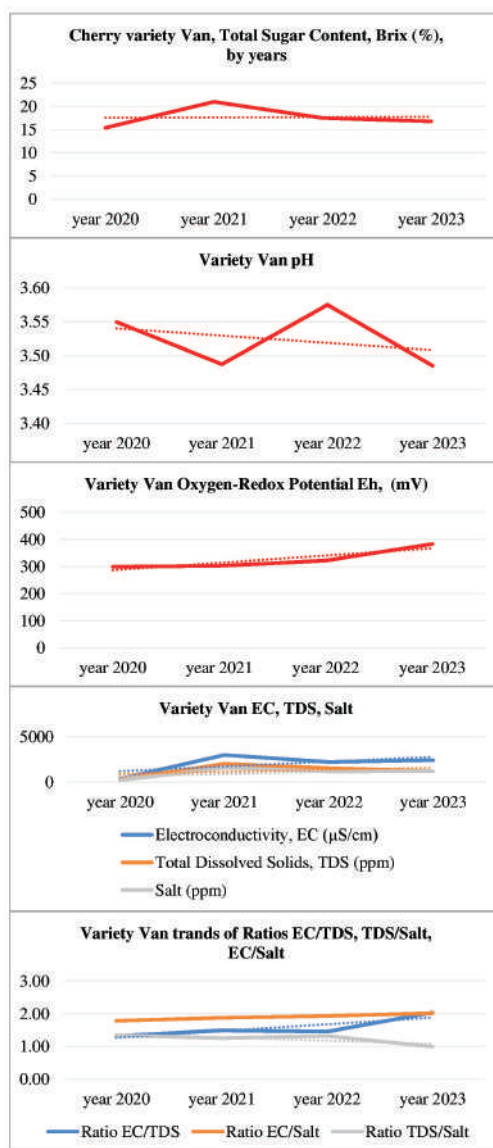


Fig. 3. Trends in the biochemistry of sweet cherry variety Van for the studied period 2020–2023: A – Trend of total dissolved sugars by Brix (%); B – Trend of acidity (pH); C – Trend of Oxygen-Redox Potential Eh; D – Trends of Electroconductivity (μS/cm), Total Dissolved Solids (TDS, ppm) and Mineral Salts (Salt, ppm); E – Trends of ratios EC/TDS, TDS/Salt, EC/Salt

and dry weather that year (Fig. 2B). The trend of Oxygen-Redox Potential Eh of sweet cherry variety Bing for the studied period 2020–2025 has a negative direction (Fig. 2C). Trends of Electroconductivity-EC ($\mu\text{S}/\text{cm}$), Total Dissolved Solids (TDS, ppm) [18–21] and Mineral Salts (Salt, ppm) increase, except for year 2023 (Fig. 2D). The trends of ratios EC/TDS increases, but ratios TDS/Salt and EC/Salt of sweet cherry variety Bing for the studied period 2020–2025 decrease (Fig. 2E).

The trend of the quantity of the total dissolved sugars is almost the same with no significant change for variety Van every year, except 2021, the trend line is horizontal (Fig. 3A), which means that the Van variety was less affected by climatic features during the period studied. The trend of the acidity pH decreases, with the exception for year 2022 (Fig. 3B). The trend of Oxygen-Redox Potential Eh has a positive direction (Fig. 3C). There are increasing trends of Electroconductivity ($\mu\text{S}/\text{cm}$), Total Dissolved Solids (TDS, ppm) and mineral Salts, mainly NaCl (Salt, ppm) (Fig. 3D). The trends of ratios TDS/Salt and EC/TDS increase, but the ratio EC/Salt decreases (Fig. 3E).

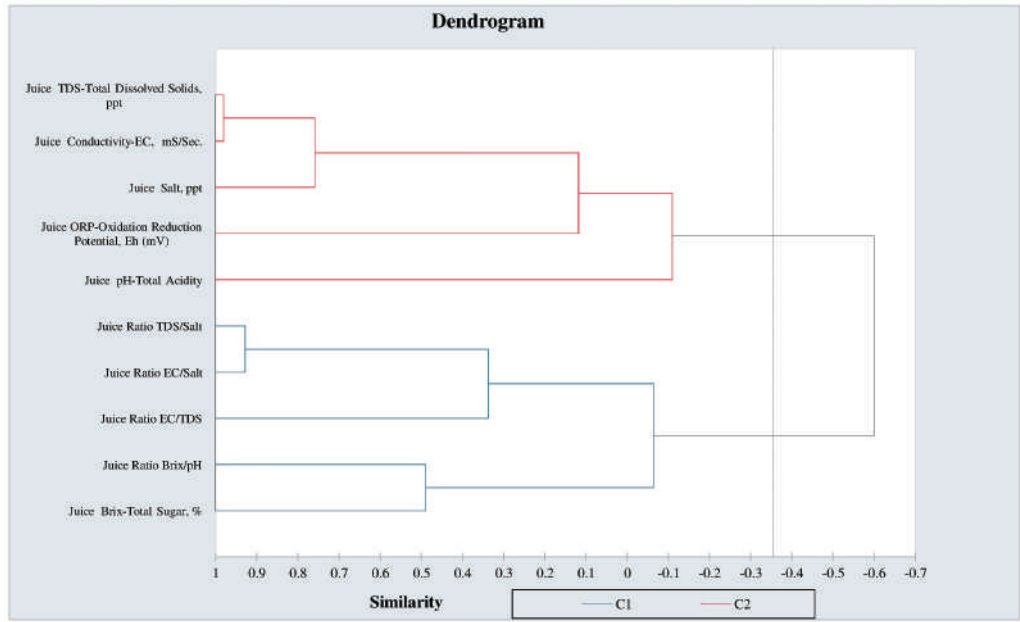


Fig. 4. Dendrogram of the Agglomerative Hierarchical Clustering (AHC) of similarity of different biochemical parameters of the cherry varieties. Pearson’s correlation coefficient $R = -0.35$

Cluster analysis shows similarity between biochemical parameters of the cherries (Fig. 4). Two main clusters are well separated: Cluster C1 correlates the total dissolved sugars with different ratios between the biochemical parameters; Cluster C2 shows very strong correlation between EC and TDS and also some correlation

with the Salts, ORP, and pH. The low electrical conductivity is due to the higher content of organic acids, which are part of the total dissolved solids (TDS), or to the presence of impurities, sediments, gases, and other degradation products resulting from anhydrous and wax appearance temperatures, suggesting that the cherry varieties studied are beginning to reach their maximum tolerance to heat and drought [18, 19].

Conclusions. The present study demonstrates that ongoing climate change in the Kyustendil valley, Bulgaria over the period 2020–2025 has had a measurable and consistent impact on the biochemical composition of sweet cherry fruits from the varieties Bing and Van. The observed increase in average air temperatures combined with a general decline in precipitation represents a clear agroclimatic stress factor that is reflected in fruit quality parameters, sugars, acids, water content, salts, Eh.

For both varieties, a general decreasing trend in total amount of dissolved sugars and changes in acidity were recorded, with more pronounced variability under extremely warm and dry conditions. At the same time, electrical conductivity, total dissolved solids and salt content – NaCl showed a clear increasing tendency, indicating concentration effects and disturbances in ionic balance caused by water stress Salt>TDS. In particularly dry years, the salt content exceeded TDS values, suggesting a disruption of normal mineral equilibrium in the fruits. Differences between the two varieties underline genotype-specific responses, with Bing showing stronger negative trends in sugar accumulation, while Van exhibiting relatively greater biochemical stability.

Correlation and cluster analyses confirmed relationships between climatic parameters and biochemical indicators, emphasizing that temperature and water availability (water/salt balance) are key drivers of changes in fruit biochemical profiles. These shifts are of practical importance for growers, processors, and the food industry, as they directly affect taste, technological suitability, and nutritional value of cherries.

REFERENCES

- [1] STOEVA A., D. SERBEZOVA (2025) Impact of climate change on some phenological behavior of sour cherry cultivars in Kyustendil region, Journal of Mountain Agriculture on the Balkans, **28**(6), 271–287, (in Bulgarian).
- [2] ZDRAVKOVA A., I. KRISHKOVA (2023) Correlations between the climatic factors and the fruit chemical composition of plum (*Prunus domestica* L.), Journal of Mountain Agriculture on the Balkans, **26**(4), 377–395.
- [3] DROGOUDI P., K. KAZANTZIS, A. KUNZ et al. (2020) Effects of climate change on cherry production in Naoussa, Greece and Bonn, Germany: adaptation strategies, Euro-Mediterr. J. Environ. Integr., **5**(12), <https://doi.org/10.1007/s41207-020-0146-5>.

- [4] EL KETTABI Z., K. ELFAZAZI, A. HADDIOUI et al. (2025) Determination and comparison of biochemical characteristics in an ex-situ collection of sweet cherry cultivars in Morocco, *Discov. Food*, **5**, 175, <https://doi.org/10.1007/s44187-025-00463-x>.
- [5] GIOVANNINI A. (2025) How cherry trees react to climate: cultivar trial in northeastern Romania, <https://cherrytimes.it/en/news/cherries-climate-cultivars-northeastern-romania-climate-change?>
- [6] PERJU I., I. MINEAȚĂ, I. E. GOLACHE et al. (2022) Influence of climate change on the phenological stages at the sour cherry genotypes, *Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. Horticulture*, **79**(2), 61–66, <https://doi.org/10.15835/buasvmcn-hort:2022.0013>.
- [7] IVANOVA I., M. SERDIUK, V. MALKINA et al. (2021) The study of soluble solids content accumulation dynamics under the influence of weather factors in the fruits of cherries, *Potravinarstvo Slovak Journal of Food Sciences*, **15**, 350–359, <https://doi.org/10.5219/1554>.
- [8] UPADYSHEVA G., S. MOTYLEVA, I. KULIKOV et al. (2018) Biochemical composition of sweet cherry (*Prunus avium* L.) fruit depending on the scion-stock combinations, *Potravinarstvo Slovak Journal of Food Sciences*, **12**(1), 533–538.
- [9] Lumivero (2025) XLSTAT, Statistical and data analysis solution, <https://www.xlstat.com/en>.
- [10] SANTOLARIA N., J. RODRIGO, E. FADÓN (2024) Adaptation of sweet cherry cultivars to future climate conditions in the Ebro Valley (Spain), *Acta Hort.*, **1408**, 425–432, <https://doi.org/10.17660/ActaHortic.2024.1408.57>.
- [11] SOTIROV A. (2024) Statistical approach in juice technology, *Int. J. Sci. Dev. Res.*, **9**(2), 761–770, <https://ijsdr.org/papers/IJSDR2402114.pdf>.
- [12] VASILISHINA O. (2017) Effect of temperature and humidity on quality score of sour cherry fruits (*Prunus cerasus* L.), *Bulg. J. Crop Sci.*, **54**(6), 35–40.
- [13] VOSNJAK M., H. SIRCELJ, D. VODNIK et al. (2022) Physio-biochemical responses of sweet cherry leaf to natural cold conditions, *Plants*, **11**(24), 3507, <https://doi.org/10.3390/plants11243507>.
- [14] WENDEN B., J. A. CAMPOY, J. LECOURT et al. (2016) A collection of European sweet cherry phenology data for assessing climate change, *Sci. Data*, **3**, 160108, <https://doi.org/10.1038/sdata.2016.108>.
- [15] XLSTAT – PRO (2025) User's guide, Addinsoft, New York, USA, Version 7.5, 1–104.
- [16] FAO (Food and Agriculture Organization) (2022) Climate change and horticulture: Adaptation strategies, <https://www.fao.org/>; <https://www.fao.org/statistics/methods-and-standards/general/en>.
- [17] Bulgarian ordinance on the requirements for fruit juices and some similar products intended for human consumption, *Bulgarian State Gazette*, No 100, 2013.
- [18] ZHANG W., X. CHEN, Y. WANG et al. (2020) Experimental and modeling of conductivity for electrolyte solution systems, *ACS Omega* 2020, **5**(35), 22465–22474, <https://doi.org/10.1021/acsomega.0c03013>.
- [19] ROBINSON R. A., R. H. STOKES (2002) *Electrolyte Solutions*. Second Revised Edition, Courier Corporation, 571 pp.
- [20] BISWAS A. (2025) Physico-chemical parameters for checking drinking water quality: a review. In: *Harmonizing Chemical and Biological Sciences for Sustainable Development*, <https://doi.org/10.31674/book.2025hcbssd010>.

- [21] RUSYDI A. F. (2018) Correlation between conductivity and total dissolved solid in various type of water: A review, IOP Conf. Ser.: Earth Environ. Sci., **118**, 012019, <https://doi.org/10.1088/1755-1315/118/1/012019>.

*Department of Agrotechnology, Plant Protection and Economics,
Institute of Agriculture-Kyustendil, 1 Sofijsko Shosse St, 2500 Kyustendil, Bulgaria
Agricultural Academy-Sofia, Bulgaria
e-mail: a_sotir@iz-kyustendil.org, <https://orcid.org/0009-0006-4078-3750>*