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Original Contribution

COMPARATIVE BIOCHEMISTRY BETWEEN PLANT FLUIDS AND THE HUMAN BLOOD

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ABSTRACT
PURPOSE: The aim is to establish regularities in the biochemistry of plant fluids and human blood. The work seeks to contribute to efforts of producing of human blood or plasma with plant origin. METHODS: Digital instrumental methods were used. Statistics was done through computer program XLStat. Reference data on the biochemistry of human blood was used. RESULTS: Some similarities and differences were found between plant fluids and the human blood. Total sugar in a human's blood is the lowest compared to studied plant fluids. Glucose in human blood is similar to that in a grapevine sap. Fructose is in lowest amount in human blood. The water in human blood is almost the same as that of plant fluids. pH of human blood is low alkaline, but plant fluids are slightly acidic to acidic. Fats in vegetables are in greater quantities in vegetables, resp. they are close to human blood. The electrical conductivity of human blood is the highest compared to the studied plant fluids. The amount of dissolved solids in human blood is close to that of vegetables. CONCLUSIONS: There is no complete similarity between the studied liquids, but they are similar in water content and they have similar ratios between biochemical indicators.

Keywords: similarity, biochemistry, plant fluids, juices, grapevine sap, human blood

INTRODUCTION

The present study is a consequence of numerous five-year observations and measurements of fluids (liquids and gases) of fruits and vegetables in two fruit and vegetable processing plants and their technological laboratories, external licensed laboratories, in the laboratories and experimental fields, a private farm and a personal laboratory. The fluids of grapevine sap and fruit and vegetable juices were considered as a kind of plant plasma and saline solution. Numerous samples and measurements have been made not only of own and local fruits and vegetables, but also of those from the store network or deliveries to the processing plants of the food industry from other regions of Bulgaria and abroad. It was found that the individual biochemical parameters are similar, regardless of the type, variety, origin and year of production of fruits and vegetables. In different years, different content of sugars or salts, different acidity or water content can be observed, but they always vary within certain limits and in general, the relationships between the individual parameters are very constant, regardless of the fact that they vary within some limits. The question whether all plant solutions are similar to each other and the results were processed statistically was therefore raised. It might be claimed that there are certain dependencies that are observed both in human blood and in plant fluids. In this study, reference data from the literature on the biochemical parameters of human blood are taken, because they are sufficiently correct, tested by practice, are reported the same in different peer-reviewed sources and coincide with the laboratory reference ranges. The research was done by food specialists with a focus on the processing of fruits and vegetables, which is why no independent study of human blood was undertaken, but only literature data were used.

Reference data on the biochemistry of human blood was used as follows: for glucose according to Güemes et al. (1); for fructose by Kawasaki et al. (2); for acidity pH by Astrup, et al. (3), because, according to Ole Siggaard-

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Andersen (4), true acidity is determined by the concentration of hydrogen ions, therefore the study of titratable acids is incorrect; for cholesterol by Goodman et al. (5); for electrical conductivity by Ištuk et al. (6); for specific gravity by Trudnowski & Rico (7); for uric acid by Ya Li Jin (8); for redox potential by Maldonado Rosas (9); for salt content by Norgaard & Gram (10); for proteins and total dissolved solids by Sparreboom et al. (11); for water by Douplik et al. (12). Data for proteins in grapevine sap information is from Zheng (13).

The aim of the study is to establish regularities in the biochemistry of plant fluids and human blood and to contribute to research on whether plant saline solutions can be used in medicine and pharmacy.

MATERIALS AND METHODS

For the implementation of the study, we used entirely digital instrumental methods, such as: a digital refractometer "Milwaukee MA871" was used to determine the total amount of dissolved sugars by (Brix, %), a digital refractometer "Milwaukee MA872" to determine the fructose content (Fru, %); the content of glucose (Glu, mmol/l), cholesterol (Chol, mmol/l) and uric acid (UA, mmol/l) was determined with a digital "Wellion Luna trio" with electrochemical biosensor technology, calibrated to blood plasma with a reference analyzer traceable to the following standard reference materials and methods: for test Glucose Standard NIST SRM 917, Glucose oxidase method. Digital refractometer "Milwaukee MA873" for glucose was used as well. For Total Cholesterol (resp. Fats) Test NIST SRM 911 Standard, Abell/Kendall Method. For uric acid test standard NIST SRM 913, Uricasa/UV method. This instrument was chosen because it is calibrated to blood plasma, i.e. it can read in the range of human blood, which is in accordance with the objectives of the study, and at the same time to avoid the difference in measurement from two different devices, one for blood and one for fruits.

Measurements were carried out in accordance with the requirements of Council Directive 2001/112/EC of 20.12.2001 of 20.12.2001 on fruit juices and certain similar products intended for human consumption, the results of which are briefly summarized in this work.

Combined digital instruments, such as conductivity meters-potentiometers were also used, as follows: "SensoDirect 150" apparatus and "Waterproof IP57" tester for determination of total acidity (pH), redox potential (Eh, V), electrical conductivity EC (mS/cm), total dissolved solids TDS (ppm,%), total salt content Salt (ppm,%), specific gravity (S.G.), temperature (t°C).

Fruit and vegetable juices by varieties were obtained by pressing method with a single shaft Star Light SJB-150 R juicer in a laboratory or in fruit and vegetable processing workshops on belt presses for cold pressing, unpasteurized, without additives, at a temperature of 20°C in normal air environment. At least 5 measurements of the biochemical parameters of each variety of fruit and vegetable were taken. All presented varieties of fruits and vegetables have been repeatedly measured in the same way in a variety of batches and harvests, variants and storages from 2020 to 2025. The data used for fats and proteins in fruits and vegetables were obtained from external licensed laboratories, respectively by the methods: for fats in vegetables Fats (%) VVLM-FH-70:2018, method error ±0.02, t=(20.0±4)°C, for proteins (proteins) in vegetables Proteins (%) in vegetables BDS ISO 1871:2014, method error ±0.03, t=(20.0±1)°C, a personal collection of protocols was used, for example, Protocol No. A5006/29.07.2022 from the Regional Veterinary Station Ruse Ltd. For fats in fruits Fats (%) BDS 6997:1984, T=20°C, RH=40%, for proteins - Proteins (%) BDS 12135:2000, T=20°C, RH=40% collection of protocols, for example, Protocol No. 7363/11.05.2022 from laboratory IL "Feba Lab". Own measurements of the fat content of fruits and vegetables, measured with a blood cholesterol testing instrument, correspond to the values obtained by external laboratories. The level of uric acid in fruits and vegetables was measured with the same blood test device. Coefficient of correlation of the data statistically processed is $r_0=0.40$ for fruits and vegetables summarized, and $r_0=0.98$, according to unpublished own data for apples.

Statistical processing was done by method described by (14) with a computer program XLSTAT (15).

RESULTS AND DISCUSSION

From the analyzes made, some similarities and differences between plant fluids and human blood can be established. **Tables 1 and 2** presents the results of the measurements of the average values of the main biochemical parameters of juices from 85 varieties of apples, 10 varieties of carrots, which are basic for the food industry in the production of fruit and vegetable juices and mixtures of them, and the results of the analyses of 30 types of main fruits, 30 types of basic vegetables and 15 varieties of vines are given. Their biochemical parameters were compared with those of human blood according to literature data, which were compared with reference data from licensed laboratories such as ABIM Laboratory Test Reference Ranges‒January 2024.

Tables 1. *Measured biochemical parameters of fruit and vegetable fluids and referent data for the human blood. *(13)*

Fluid	Brix, %	Glucose, Glu, mmol/l	Fructose, Fru, %	Acidity, pH	Fats, mmol/l (Cholesterol, mmol/l)	Proteins, % (external laboratories)	Electroconductivity, EC, mS/cm
Human blood (reference values*)	4.50	4.50	1.60	7.40	5.15	6.90	5.37
Apples	12.30	28.30	19.09	3.67	1.49	0.33	1.88
Carrots	8.10	30.80	7.90	6.10	0.37	0.54	4.60
Different vegetables	6.10	14.30	8.60	5.72	4.60	0.54	4.57
Different fruits	15.30	27.80	15.19	3.67	0.20	0.10	2.25
Grapevine sap	0.17	1.29	1.00	5.54	1.00	0.04*	0.59

Table 2. *Measured biochemical parameters of fruit and vegetable fluids and referent data for the human blood. *(13)*

Fluid	Total Dissolved Solids, TDS, %	Salt, %	Specific Gravity S.G.	Uric Acid UA, mmol/l	Redox-potential, Eh, V	Water yield (approx.), %
Human blood (referent values*)	3.00	0.46	1.051	0.36	0.148	49.50
Apples	0.10	0.09	1.001	0.55	0.278	49.53
Carrots	3.40	2.50	1.055	0.66	0.108	43.30
Different vegetables	3.62	3.11	1.002	1.70	0.050	40.02
Different fruits	1.45	1.14	1.001	0.87	0.108	40.01
Grapevine sap	0.03	0.03	1.000	1.00	0.017	47.07

Figure 1 illustrates the distribution of the measured biochemical parameters of fruit and vegetable fluids and reference data for the biochemistry of human blood. For the total amount of dissolved sugars in the human blood, we accepted the glucose level and therefore Brix and Glu are shown in equal amounts. Fig. 1 shows that the level of total sugar in a healthy person is the lowest level compared to the other plant fluids used for comparison, with the exception of grapevine sap, with the juice of average value of studied fruits having the most glucose, followed by apples, carrots and average values of glucose of studied vegetables, which are closest to human blood and rather close to blood plasma, in which the values are

slightly higher, according to the ABIM Laboratory Test Reference Ranges‒ January 2024.

With regard to glucose, only the average values of the grapevine sap are lower than those of human blood, but it should be borne in mind that some individual samples of grapevine sap have higher glucose values. So, in terms of glucose content, human blood is most similar to the grapevine sap. Carrots have the highest glucose content and are equal to the average values of data on juices from different types of fruits and apples. The average values of different types of vegetables have a lower glucose content, almost two times lower than that of fruits, but again they have many times higher glucose content than that of human blood, even in blood plasma.

A characteristic of fructose is that the lowest amounts are in human blood and in grapevine sap, and the highest in apples and then in different fruits on average. In carrots and different types of vegetables fructose is on average almost half as much, but it is still 3 times higher than the blood and grapevine sap.

The water content in human blood can be said to be almost the same as that of apples and almost as to other studied plants, which can be obtained by the method of cold pressing or about 50%, although in Tables 1 and 2 and Fig. 1 are given average measured values, but our experience shows that in both fruits and vegetables the juice content most often varies between 40-60%, depending on their degree of freshness and dehydration, i.e. approximately around the water content of human blood, and the excreted liquid, called grapevine sap, is also in this amount when extracted by pressing. In terms of water content, human blood resembles all the plant fluids examined, which can be produced by normal pressing with a pressure of 2.5 atm. at room temperature, approximately a content of about 50%.

In terms of the acidity pH of the solutions, human blood is very slightly alkaline with a pH value of = 7.40 in contrast to all studied plant fluids, which range from slightly acidic in carrots and vegetables pH = 5.8-6.0 to acidic in apples and fruits with pH = 3.5-3.8 **(Figure 1).**

Fats in vegetable fluids, respectively total cholesterol in human blood are in greater quantities in vegetables, which approach their amount in human blood Chol (Fat) = 4.6-5.15 mmol/l, followed by apples and of grapevine sap with almost three times smaller amounts and insignificant presence of fats in carrots and various fruits.

Proteins are in the highest amount in human blood at about 6.9%, and the studied plant fluids contain proteins below 1%, while in carrots and on average for vegetables the amount is the same: Proteins = 0.54%. In the case of apples and fruits, they are generally in minimal quantities, and in the case of the grapevine sap they appear only as traces and cannot even be reflected on the diagram **(Figure 1).**

The electrical conductivity of human blood is the highest compared to the studied plant fluids EC=5.37 mS/cm. It is close to that of carrots and vegetables as a whole EC=4.5-4.6 mS/cm. Apples and fruits have about twice lower electrical conductivity of their juices, and grapevine sap has the lowest electrical conductivity EC=0.59 mS/cm **(Figure 1) (Tables 1 and 2).**

The total amount of dissolved solids is in the largest amount in vegetables and carrots TDS = 3.40-3.62%. Their amount in human blood is close to about 3%, while in apples and especially in vine sap they are in minimal quantities.

Since the amount of salt NaCl is not much in human blood – on average Salt = 0.46%, it is likely that the high electrical conductivity is due to the high amount of dissolved solids – minerals and organic substances. Salts are almost absent in apples and grapevine sap and are in the form of impurities, while in carrots and vegetables they are several times higher than the levels in human blood about 2.50-3.11%.

The specific gravity of all the studied fluids is lower than the same of the human blood, which is S.G. = 1.051 and thus is closest to the specific gravity of carrots 1.055. The vine sap has a specific gravity of 1.000, which is closest to that of water, and the apple and various fruits have S.G.=1.001.

Uric acid is in lowest amount in the human blood of healthy people, respectively UA=0.36 mmol/l **(Tables 1 and 2, Figure 1).** This is followed by apples and carrots, which have similar amounts of uric acid, followed by the different fruits and grapevine sap, and different types of vegetables have the highest uric acid content in their juices. The U.S. Department of

Agriculture provides information on the content of purines, which are a source of uric acid in various types of foods, including fruits and vegetables, and the reference used (16).

The redox potential (ORP) is highest in apples, i.e. they are the easiest to oxidize, followed by human blood, almost equal to carrots and fruits with Eh=0.148 mV. The values and respectively the oxidation-reduction ability of different vegetables are lower, and the lowest Eh values are of the grapevine sap**. Figures 12 and 13** represent the statistical processing of the data of **Tables 1 and 2** done by XL STAT (14,15).

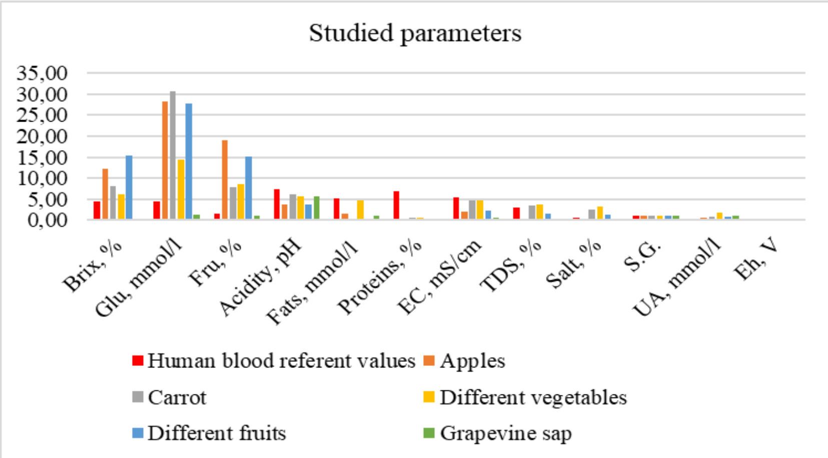

Figure 1. Distribution of the measured biochemical parameters of fruit and vegetable fluids and referent data for the human blood biochemistry.

In **Figure 2** the lines linking the values of the individual biochemical parameters of the human blood with those of the studied plant fluids are compared. Apparently, they almost coincide in the direction of the water content, and differ mainly in terms of the various types of sugars and acidity of the solution.

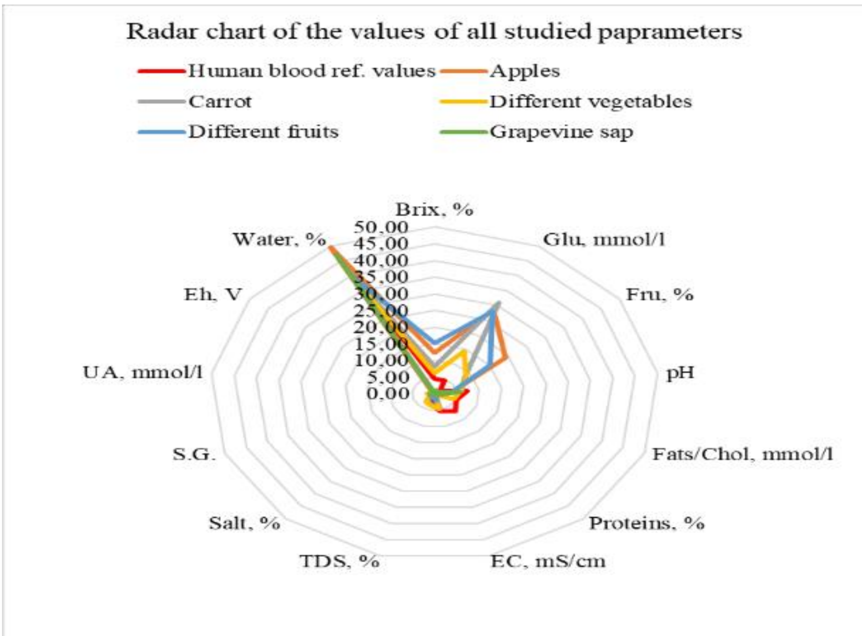

Figure 2. Radar diagram of the biochemical parameters of the human blood and plant fluids.

Tables 3 and 4 present the relationship between the values measured on the biochemical parameters of human blood and those of the studied plant fluids. The data are statistically illustrated by a radar diagram **(Figure 3),** on which the ratios of human blood to studied fluids and the ratios of biochemical parameters of apples to carrots are superimposed. These plants provide the main fruit and vegetable base juices in the food industry and range widely in the production of own food products. They can be mixed with many other products, while keeping high nutritional value and utility.

***Table 3**. Ratios between measured biochemical parameters of fruit and vegetable fluids and reference data for the human blood fluid biochemistry.*

Ratios	Brix, %	Glucose, Glu, mmol/l	Fructose, Fru, %	Acidity, pH	Fats, mmol/l (Cholesterol, mmol/l)	Proteins, %	Electroconductivity, EC, mS/cm
Ratios Blood/Apples	0.37	0.16	0.08	2.02	3.46	20.91	2.86
Ratios Blood/Carrots	0.56	0.15	0.20	1.21	13.92	12.78	1.17
Ratios Apples/Carrots	1.52	0.92	2.42	0.60	4.03	0.61	0.41
Ratios Blood/Vegetables	0.74	0.31	0.19	1.29	1.12	12.78	1.18
Ratios Blood/Fruits	0.29	0.16	0.11	2.02	25.75	69.00	2.39
Ratios Blood/Grapevine sap	26.47	3.49	1.60	1.34	5.15	172.50	9.04

***Table 4.** Ratios between measured biochemical parameters of fruit and vegetable fluids and reference data for the human blood biochemistry.*

Ratios	Total Dissolved Solids, TDS, %	Salt, %	Specific Gravity S.G.	Uric Acid UA, mmol/l	Redox-potential, Eh, V	Water yield (approx.), %
Ratios Blood/Apples	30.00	5.11	1.05	0.66	0.53	1.00
Ratios Blood/Carrots	0.88	0.18	1.00	0.54	1.37	1.14
Ratios Apples/Carrots	0.03	0.04	0.95	0.83	2.57	1.14
Ratios Blood/Vegetables	0.83	0.15	1.05	0.21	2.97	1.24
Ratios Blood/Fruits	2.07	0.40	1.05	0.41	1.37	1.24
Ratios Blood/Grapevine sap	86.21	15.33	1.05	0.36	8.72	1.05

Radar diagram of the ratios between the biochemical parameters of human blood and those of plant fluids **(Figure 3)** shows similar values of the ratios of biochemical parameters of human blood related to those of the studied plant fluids.

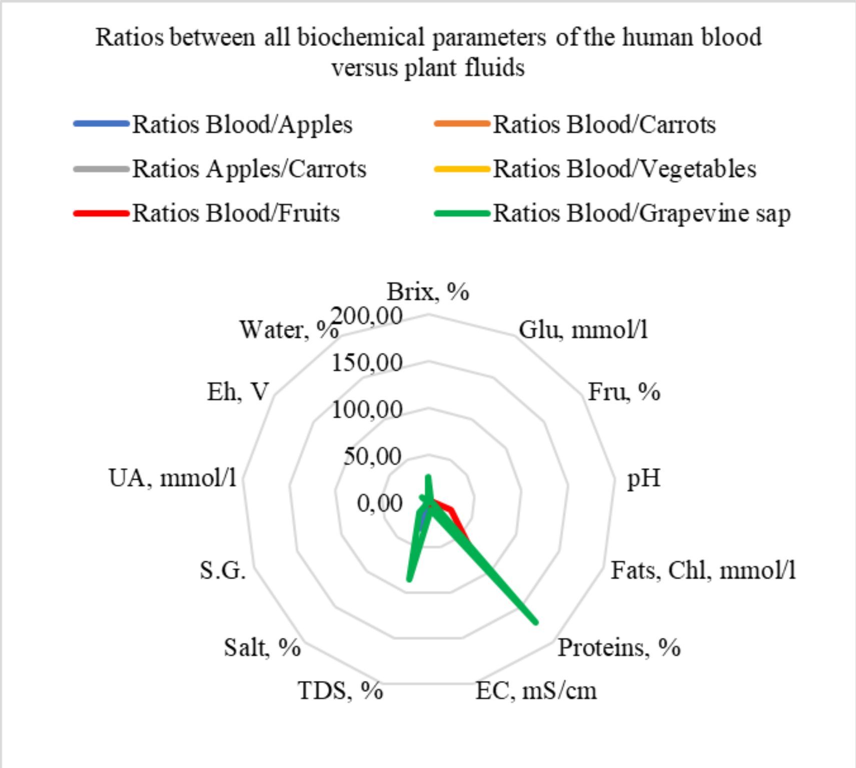

Figure 3. Radar diagram of the ratios between the biochemical parameters of human blood and those of plant fluids.

Figure 4 shows that the different types of sugars have a mutual positive correlation - a relationship in all studied liquids, incl. and in human blood, i.e. when one of the sugars increases, the amount of the other two increases, and all the studied sugars have an inverse (negative) correlation with the acidity of the solution, i.e. the sugars are directly related to acidity, i.e. at a lower pH value, the amount of sugars increases and vice versa.

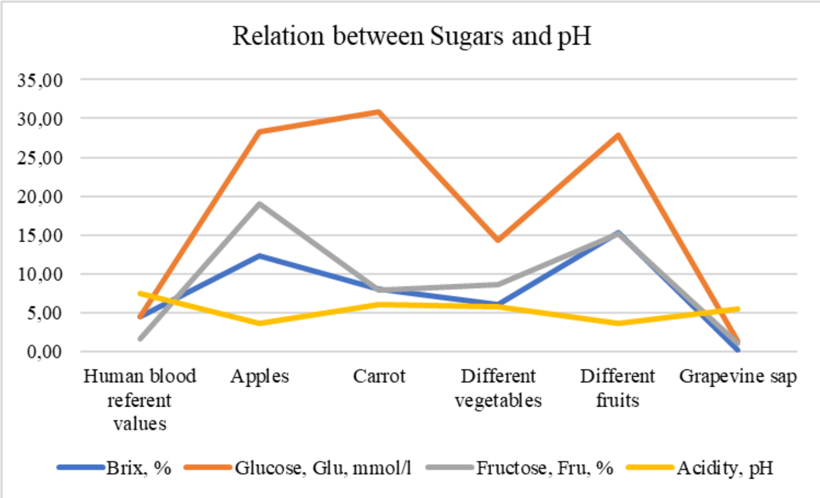

Figure 4. Relationship between sugars and acidity of solutions by type of liquid.

The ratios between the sugars of the studied liquids are positively correlated, which can be seen at **Figure 5**, and also with the redox potential of the liquids Eh **(Figure 6).** There is also a poorly defined positive correlation between fats and proteins with the acidity **(Figure 7).**

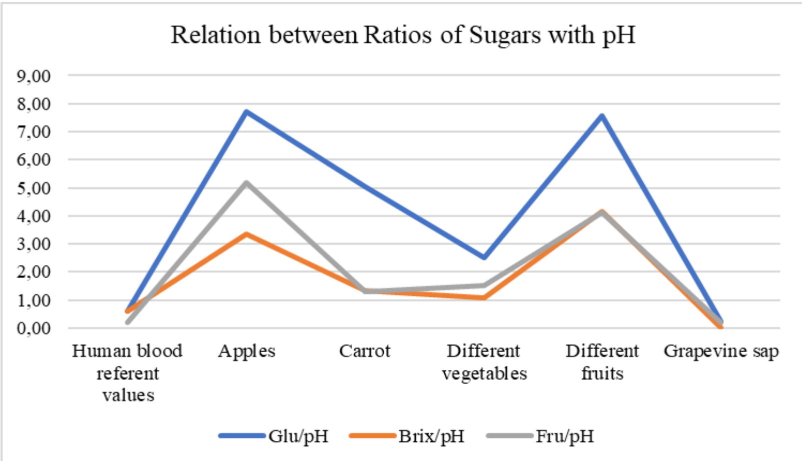

Figure 5 Relationship between the ratio of sugars with acidity pH of the solutions.

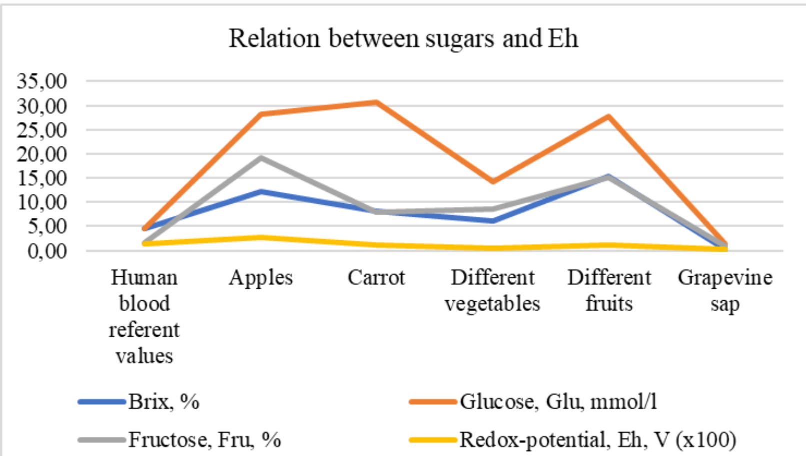

Figure 6. Relationship between sugars and redox potential.

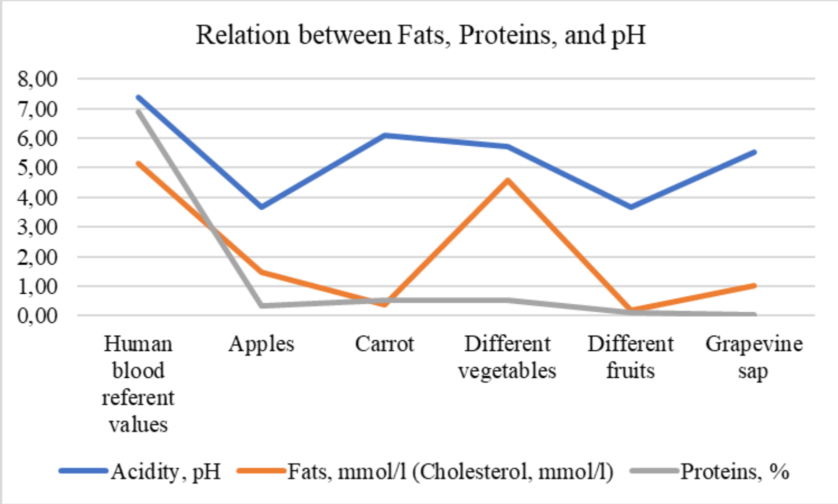

Figure 7. Relationship between fats, proteins and acidity pH.

There is a positive correlation between uric acid and the acidity of the studied average values of fruits and vegetables, but it is not observed in human blood, grapevine sap, apples and carrots **(Figure 8).**

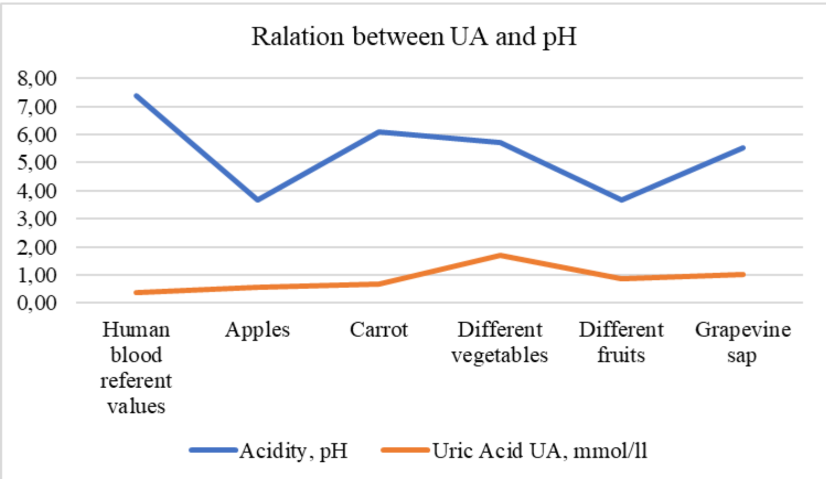

Figure 8 Relationship between uric acid and acidity pH.

It should be emphasized that in general, there is a strong negative correlation of the relationship between uric acid and acidity pH in all the studied liquids, except for human blood, and a positive relationship between the ratios of these two parameters **(Figure 9)**.

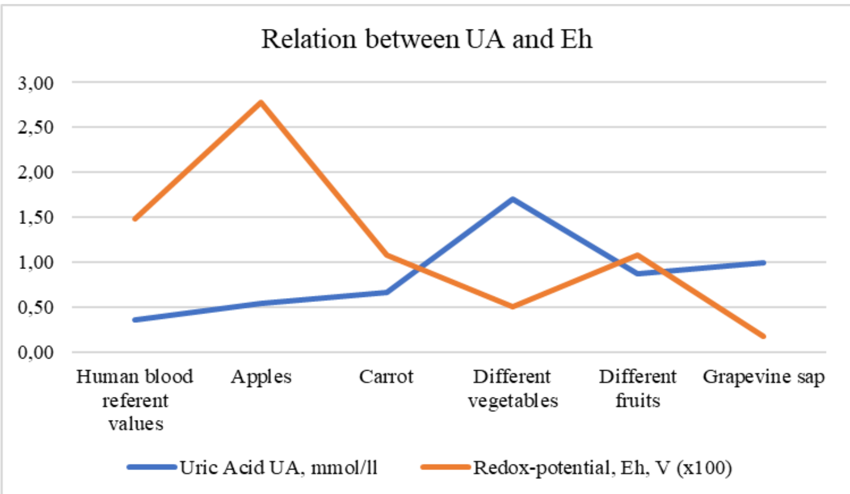

Figure 9 Relationship between ratios of uric acid and acidity pH.

The positive relationship between electrical conductivity, total dissolved solids, salt and acidity is markedly pronounced. These indicators are strongly dependent on each other, with a slightly weaker correlation observed in their relationship with the acidity of human blood **(Figure 10).**

Exactly the opposite strong but negative correlation is observed between electrical conductivity, total dissolved solids, salt and redox potential Eh, which, however, in fruits and grapevine sap the correlation is positive.

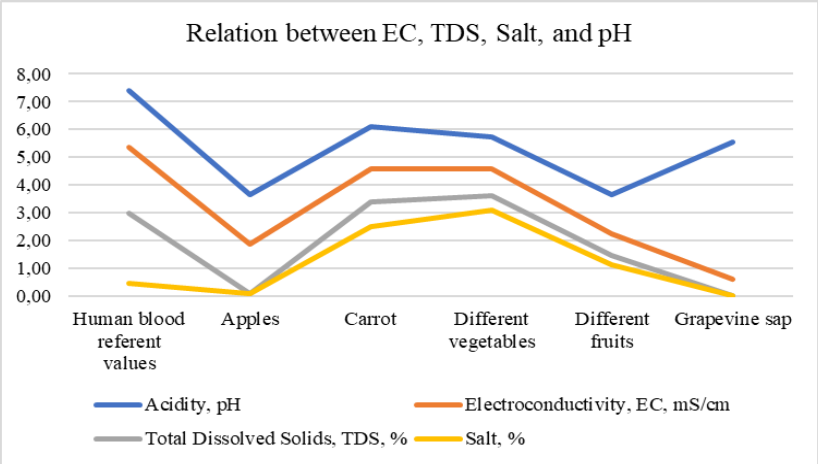

Figure 10. Relationship between electrical conductivity, total dissolved solids, salt, and acidity.

There is also a poorly defined positive correlation between fats and proteins with acidity. The correlation between uric acid and the acidity of the studied average values of fruits and vegetables is positive, but it is not observed in human blood, grapevine sap, apples and carrots. A strongly negative correlation of the relationship between uric acid and acidity pH was observed in all studied fluids, with only human blood making an exception here and being in a positive relationship between the ratios of these two parameters. The positive relationship between electrical conductivity, total dissolved solids, salt and acidity is strongly pronounced. These indicators are highly dependent on each other, with a slightly weaker correlation observed in their relationship with the acidity of human blood. Strong, but negative correlation is observed between electrical conductivity, total dissolved solids, salt and redox potential Eh, which, however, in fruits and grapevine sap turns into a positive correlation **(Figure 11).**

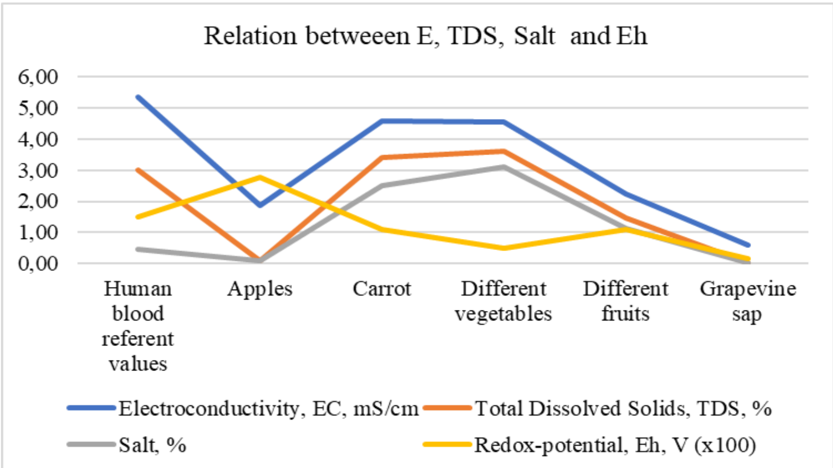

Figure 11. Relation between measured biochemical parameters of fruit and vegetable fluids and human blood.

Data was processed statistically. Box-plots of mean, minimum and maximum measured values are presented in **Figure 12.** The histograms of the measured parameters are given in **Figure 13**.

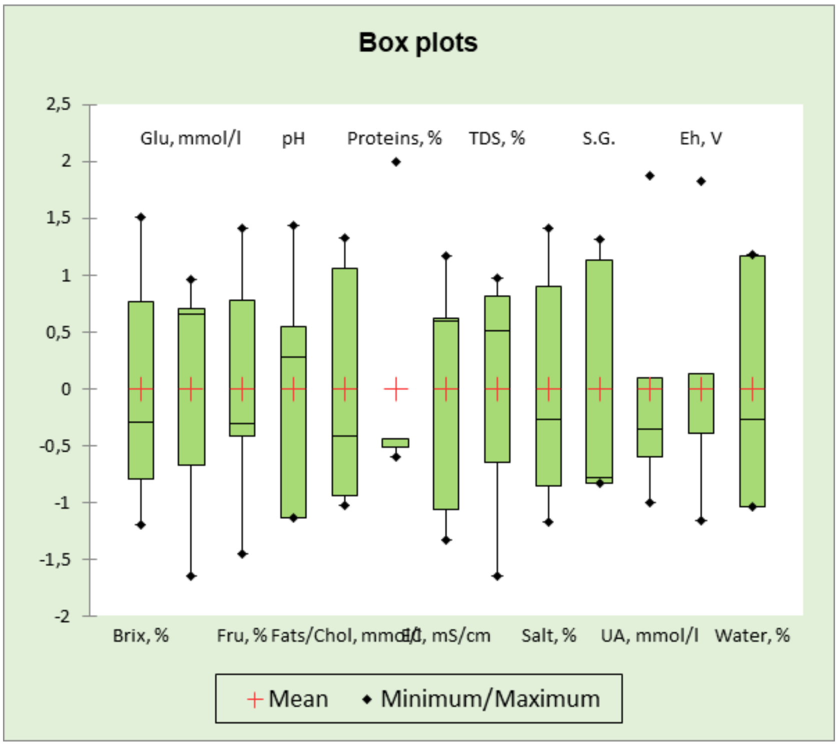

Figure 12. Box plots, results of the processing of the statistical data.

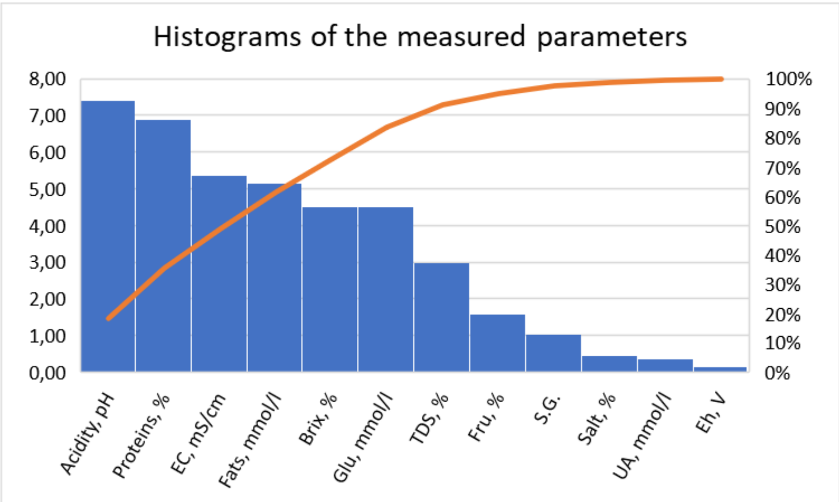

Figure 13. Histograms of the measured parameters.

Figure 14 shows where the studied biochemical parameters are situated on the Eh-pH diagram of Porbaix (17). The diagram shows the chemical equilibrium of the water solution. It can be seen that the closest to the middle in the range of water stability limits – the strip between lines ***a*** and ***b*** is the human blood, followed by plant fluids. At the top of the diagram, above line ***b*** fluids can be oxidized, with oxygen gas production while at the bottom, below line ***a*** are reducing conditions with hydrogen gas production.

Figure 15 shows where the studied biochemical parameters are situated on the TDS-Salt diagram (18). Only grapevine sap falls on the line of equilibrium between total dissolved solids and salt. Fruits and vegetables, including apples and carrots, fall into the zone with unsaturated salt solutions, and human blood differs greatly from other fluids by the much lower amount of salt than the saturation level of the solution. TDS means salt plus other dissolved chemicals or element as organic acids, for an example.

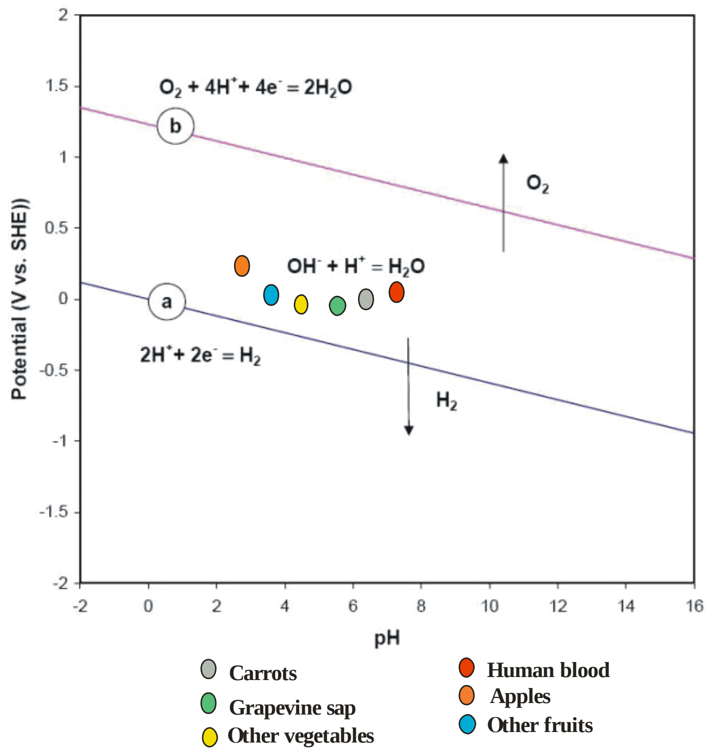

Figure 14. Place of the human blood, apples, carrots, different fruits, different vegetables, and grapevine sap on pH-Eh Pourbaix diagram (Penchev et al., 1990).

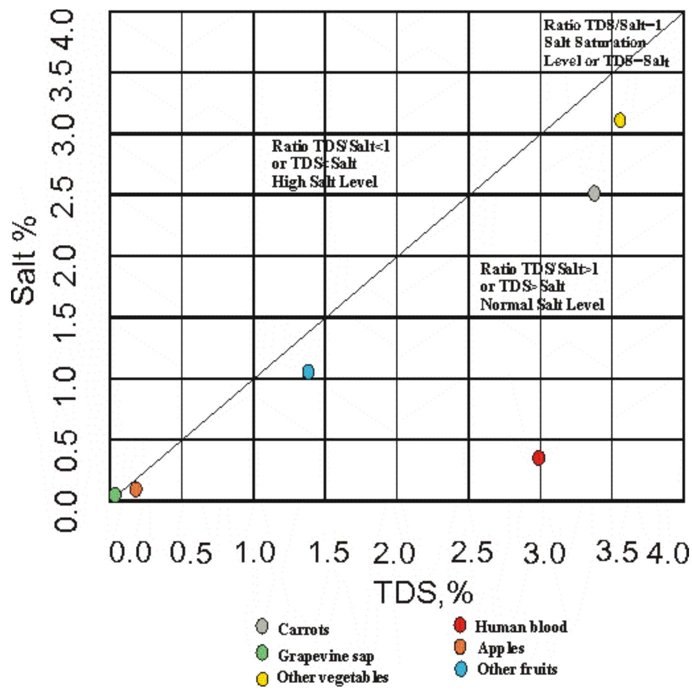

Figure 15. Place of the human blood, apples, carrots, different fruits, different vegetables, and grapevine sap on TDS-Salt Diagram (18)

CONCLUSION

In conclusion, it can be said that in the biochemistry of human blood, like the biochemistry of plant fluids, there are a number of regularities, such as precisely defined ranges and levels of components, precisely defined relationships between them. There are identical dependencies and ratios. Human blood is similar in biochemical parameters to some plant fluids or to other plants. Human blood is located in the central place in the diagram of the water equilibrium between oxidation and reduction of water in itself and is distinguished most by its place in the TDS-Salt diagram, being located farthest from the equilibrium line between salts and dissolved solids, or in a word, the highest measured electrical conductivity in human blood, compared to plant fluids, is not at the expense of salt as an electrolyte, but due to the higher content of other dissolved organic substances in the blood. In the search for suitable plant fluids as substitutes for human blood or plasma, the rule that the biological optimum of plants (the optimum of living matter) is a natural continuation of the thermodynamic state of weathering crust and soil (19) helps, and finding the most suitable plant fluid for this purpose will be an indicator of the connection between man and planet Earth.

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