Statistical Approach in Juice Technology

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***Abstract* - The aim of the study is to apply a statistical approach to analyse the data obtained from the study of the technological parameters of fruit and vegetable juices for a three-year period from 2020 to 2023 in the fruit and vegetable processing plants - Kyustendil region, Bulgaria. The results obtained by the statistical approach and especially by the Cluster Analisis are more than satisfactory: Similarities: Cluster C1: Association 1: all vegetables are united in one cluster, meaning very different technical parameters than the fruits. Interesting here is that some fruits as watermelon, melon, grapefruit and blackberry are included into the vegetable group, on the basis of dissimilarities of their technological parameters of the juices; Cluster C2: Association 2: all fruits are grouped in one association totally different by technological parameters than the vegetable association 1. Dissimilarities: Cluster C1: Association 1: of all fruits from lemon - to sweet red cherry are grouped in this association; Association 2: pumpkin-celery-leaves-potato-onion-corn-water melon-melon, red tomato; Cluster C2 united the green vegetables: Association 1: green bean-zucchini-green pepper-green tomato-cabbage-eggplant-green pepper-green tomato-cabbage-eggplant; Association 2: spinach-red beetroot-carrot-celery root-celery; Celery stem is the united of the associations and it is common for Ass. 1 and Ass. 2.**

Keywords: **statistics, cluster analysis, juices, technology, fruits, vegetables.**

I. Introduction

The aim of the work is to be investigated and statistically processed some basic technological parameters of fruits and vegetables delivered for food canning industry in Kyustendil Region, Bulgaria for 3-years period. 29 types of fruits and 16 types of vegetables, big part of them grown by the Institute of Agriculture in town of Kyustendil, other part are delivered by the local farmers, and third part is imported by other regions of Bulgaria or foreign countries. The experimental procedure was selected according to the Bulgarian and European legislation.

Fruits and vegetables are one of the the main raw materials for the food industry and cooking in terms of fruit. They are the main raw materials in a wide range of productions in the food industry. It is an indispensable fruit for direct consumption, canning, as well as in cooking and confectionery for various dishes.

Statistical processing allows data to be analyzed and conclusions to be drawn that are difficult to be without data processing. For example, the cluster analysis shows that the fruits and vegetables used can be divided into groups with the same or similar technological properties and indicators. This allows saves many chaotic attempts in laboratories on the principle of trial-error. It can be determined which fruits and vegetables can be combined, mutually substituted, and not only organo-leptic, but also in terms of food safety. For example, when mixing juices with high acidity and those with higher alkalinity, chemical reactions may occur, not always with a positive effect. You can get new substances, worsen the quality of the juice by obtaining sediments, unpleasant color, for example, when mixing red and green color, brown is obtained. We take in watermelon and melon as fruits, but in fact the cluster analysis integrates them to vegetables according to their technological indicators and more precisely according to their behavior when changing conditions. This does not seem wrong at all, because indeed, every technologist is confronted with the peculiarities of these two fruits, which in raw form have a taste like a fruit, but when trying to get juice from them, the juice is not very pleasant and rather resembles to cucumber or pumpkin.

Statistic is used from many authors for processing of analitical data in the fod industry, must mention Simunaniemi et al. (2013), Ying et al. (2019), Henrique et al. (2013), Ward (1963), Qannari (1997), Johnson and Wichern (2002), Dahl and Naes (2004).

II. Materials and Methods

The aim of the study is to use statistical approach and especially Cluster Analysis for the interpretation of technological data from juice studies of 45 different fruits and vegetables, used as raw material for production of cold-pressed, cloudy, pasteurized fruit, vegetable and mixed fruit-vegetable juices in the fruit and vegetable processing plants on the territory of Kyustendil Region, Bulgaria. Portable digital instruments were used *in situ* at fruit and vegetable processing line for higher accuracy and quickness of the measurements as follow: Refractometer “Milwaukee Brix MA871”- Hungary to measure the total sugar content by Brix (%) and refractometer “Atago-Pal 1” for control, Australia, instrument "Lovibond-SensoDirect 150"-United Kingdom and Bluetooth compatible water quality intelligent tester “Yieryi BLE-C600”-China for control are used for determination of total acidity (pH), electrical conductivity (EC, mS/cm), total dissolved solids (TDS, ppt), total salt content (Salt, ppt), Specific Gravity (S.G.), Eh - Redox potential (V) of the juices, and temperature (°C). The juices were produced by the cold-pressing method, using 2,5-3,5 atm. pressure of the press, speed of the grinder 35 Hz, speed of the belt-press 48 Hz, temperature 20°C in regular air environment. Measurements were done from July 2020 to July 2023, every day. Minimum 30 measurements of technological parameters were used for each kind of fruits and vegetables at the present study. The statistical processing of the data was performed by using computer application XLStat-Pro. Technological parameters for research were studied, according to *Bulgarian State Gazette No* 100 (2013) *(9)* and *Decree No 217 of 29 July 2022 adopting an Ordinance on the requirements for fruit juices and certain similar products intended for human consumption*. It is focused on Cluster analysis, which allows for grouping data by their similarities and differences and valuable conclusions about the technological process can be drawn when comparing them

The unification of different types of fruits and vegetables by similarities of their technological and organo-leptic indicators makes it possible to replace the different types of raw material or replace them by varieties so that they fit technologically and organo-leptically each other. In the absence of supplies of certain fruits and vegetables, substitutes can be selected, new recipes for mixing individual fruits and vegetables can be developed to achieve excellent nutritional and technological qualities of the juice.

III. Results and Discussion

Tables 1 and 2 show the averaged results of 30 measurements for each type of fruits and vegetables for 6 technological indicators of the juices or ground mass derived from them, respectively Total amount of sugars by Brix, total acidity pH, electrical conductivity EC, total dissolved solids TDS, total amount of Salt and redox potential Eh. The relationships between them are also shown.

Fig. 1 shows the total sugar content by Brix (%) of the juices, produced by the cold-pressed method of the studied 29 fruits and 16 vegetables. The figure shows well the distribution of sugar by fruit or vegetble, as it is clearly seen that the fruits as a whole contain more sugars, but also the difference in contents varies with a greater amplitude, indicated by the blue line. The red line shows the average contents of the total amount of sugars in vegetables, which clearly shows that the sugar content of vegetables is less than in fruit, but the difference in minimum and maximum measured values vary in a rather narrower range.

Fig. 2 Total acidity pH of the fruit and vegetable juices (blue line for fruits, red line for vegetables)

Fig. 2 shows the same trend of the total acidity of juices as sugar content at Fig. 1 or the total acidity is higher in fruits than the vegetables, but variation of the values are grater. Acidity of the vegetables is lower with shorter differences between the values of the different kinds of vegetables.

Fig. 3 follows the image in Fig. 2. It shows the ratio Brix/pH sugar content on acidity and the final value is lower for vegetables and higher for fruit. Ratio Brix/pH values the mix between sweetness and sourness of fruits and vegetables as current authors having published works describing the most approved relationships of these two technological parameters by the end user, and this is the ratio Brix/pH=3.5-4.5 (Sotirov et al. 2021). In other words, the diagram shows that fruits in most cases than the vegetables are approved as taste indicators by humans.

Fig. 4 presents a diagram of all other the studied technological parameters of the fruit and vegetable juices EC, TDS, Salt. It is seen than opposite of the data for pH and sugar content all other studied parameters of fruit juices have lower values and lower variables of the values than the vegetable juices. On Fig. 5 Ratios EC/TDS, Ratio TDS/Salt are in vice version relation with, but Ratio EC/Salt relates with Ratio EC/TDS

Figs 6 and 7 are histograms showing the most measured values of the studied technological parameters of the fruit and vegetable juices. For an example Total Sugar Content of fruits vary between 5 and 35%, as the most measured values are 10-15% and second group of measurements are 5-10% and 15-20%. Acidity of the fruits is mostly 3-4, but acidity of the vegetables is mainly 5,5-6,5. Fig. 8 presents visually the measured technological parameters between fruit and vegetable juices as fruits have higher sugar content and acidity than the vegetables and as well as the ratios between the parameters are also higher, but very close to these of the fruits.

Very interesting location is observed when apply Eh-pH water diagram for the juices. All of them are located a little bit above the border line (a) where is the place of losing of Hydrogen executes or all kind of juices, or all of the juices are a subject to oxidation. All of them need antioxidant – for an example ascorbic acid for recovering of the lost hydrogen. But the most useful statistical approach is the Cluster analysis. It gives totally different view on the data and it is a valuable analysis for interpretation of the data from the laboratory measurements of each food processing plant. Tables 3 and 4 and Fig. 10 present the data processing of the measured technological parameters of the different kinds of juices from Agglomerative hierarchical clustering (AHC) Similarities between the data. As a result of the statistical cluster analysis we have separated two main clusters C1 and C2.

Cluster C1 in blue line of Fig. 10. is composed by a dozen of associations and sub-associations, united according to their origin and genesis, common chemical content, common behaviour under changing of the conditions of the environment, common taste, colour or aroma - or common technological parameters. These are fruits and vegetables which might be replaced and changed, they complement each other, they might be mixed in different ratios to achieving of the best quality for the users:
Cluster C1:
Association 1: of all fruits from lemon - to sweet red cherry;
Association 2: pumpkin-celery-leaves-potato-onion-corn-water melon-melon, red tomato;
Cluster C2 united the green vegetables:
Association 1: green bean-zucchini-green pepper-green tomato-cabbage-eggplant-green pepper-green tomato-cabbage-eggplant
Association 2: spinach-red beetroot-carrot-celery root-celery;
Celery stem is the united of the associations and it is common for Ass. 1 and Ass. 2.
Many researchers present only data analysis through similarity, but the comparison of cluster diagrams between similarity and dissimilarity shows hidden dependencies and can serve as very valuable inferences. For example Fig. 11 and Tables 5 and 6 interesting aggregations of data with or even incompatible technological origin and genesis, common chemical content, common behaviour under changing of the conditions of the environment, common taste, colour or aroma - or common technological parameters. Two clusters C1 and C2 are distinguished again.
Cluster C1: Association 1: all vegetables are united in one cluster, meaning very different technical parameters than the fruits. Interesting here is that some fruits as watermelon, melon, grapefruit and blackberry are included into the vegetable group, on the basis of dissimilarities of their technological parameters of the juices;
Cluster C2: Association 2: all fruits are grouped in one association totally different by technological parameters than the vegetable association 1.

Table 1. Measured technical parameters of different fruit juices.

	Brix-total sugar, %	**pH-acidity**	**EC-Conductivity, mS/cm**	**TDS-total dissolved solids, ppt**	**Salt, ppt**	**Eh-redox potential, V**	**Ratio Brix/pH**	**Ratio EC/TDS**	**Ratio TDS/Salt**	**Ratio EC/Salt**
Apple Red	14,7	3,50	1,75	1,19	0,88	0,067	4,20	1,47	1,35	1,99
Apple Yellow	14,2	3,40	1,50	1,02	0,75	0,049	4,18	1,47	1,36	2,00
Apple Green	11,5	3,99	1,54	1,09	0,77	0,062	2,88	1,41	1,43	2,00
Apricot	15,8	3,00	3,35	2,30	1,78	0,260	5,27	1,46	1,29	1,88
Aronia	31,0	3,60	3,00	2,05	1,58	0,078	8,61	1,46	1,30	1,90
Banana	16,4	5,02	2,16	1,44	1,10	-0,007	3,27	1,50	1,31	1,96
Blackberry	9,6	3,40	3,39	1,69	1,70	0,335	2,82	2,01	0,99	1,99
Cherry Red	23,1	3,50	2,69	1,82	1,37	0,152	6,60	1,48	1,33	1,96
Cherry Sour	15,9	3,10	2,98	2,03	1,56	0,192	5,13	1,47	1,30	1,91
Cherry White	17,9	3,60	2,74	1,86	1,43	0,005	4,97	1,47	1,30	1,92
Grape Red	17,0	3,00	1,37	0,93	0,68	0,136	5,67	1,47	1,37	2,01
Grape White	17,0	3,30	1,38	0,94	0,68	0,146	5,15	1,47	1,37	2,01
Grapefruit	8,8	2,95	3,21	2,15	1,64	0,075	2,98	1,49	1,31	1,96
Kiwi	13,9	3,43	4,80	2,42	2,50	0,208	4,05	1,98	0,97	1,92
Lemon	7,1	2,30	1,74	1,17	0,86	0,066	3,09	1,50	1,35	2,02
Melon	9,7	5,97	4,93	3,31	2,37	0,044	1,62	1,49	1,40	2,08
Orange	12,5	3,50	3,16	2,17	1,69	0,078	3,57	1,46	1,28	1,87
Peach	16,8	3,70	1,11	0,74	0,53	-0,063	4,54	1,50	1,40	2,11
Pear	13,6	3,60	1,47	1,01	0,80	0,042	3,78	1,45	1,27	1,84
Pear Serv. tree	26,2	3,92	1,47	0,98	0,73	0,189	6,68	1,49	1,34	2,00
Plum Blue	22,7	3,30	2,53	1,73	1,34	0,095	6,88	1,46	1,29	1,89
Plum Red	15,2	3,16	1,73	1,18	0,88	0,158	4,81	1,47	1,34	1,96
Plum White	16,6	4,20	1,02	0,68	0,50	0,075	3,95	1,49	1,37	2,04

Plum Yellow	15,3	3,10	1,83	1,20	0,94	0,116	4,94	1,52	1,28	1,95
Pomegranate	16,4	3,42	1,73	1,12	0,84	0,288	4,80	1,54	1,34	2,07
Pumpkin	5,5	6,34	4,19	2,09	2,00	0,010	0,87	2,00	1,05	2,10
Quince	15,7	2,56	0,37	0,25	0,18	0,120	6,13	1,51	1,40	2,11
Raspberry	15,8	3,20	0,78	0,52	0,37	0,065	4,94	1,50	1,38	2,07
Watermelon	7,8	5,46	1,38	0,95	0,69	0,094	1,43	1,46	1,37	2,00
Average for Fruits	***15,3***	***3,67***	***2,53***	***1,73***	***1,34***	***0,108***	***4,41***	***1,53***	***1,30***	***1,98***

Table 2. Measured technical parameters of different vegetable juices.

	Brix-total sugar, %	**pH-acidity**	**EC-Conductivity, mS/cm**	**TDS-total dissolved solids, ppt**	**Salt, ppt**	**Eh-redox potential, V**	**Ratio Brix/pH**	**Ratio EC/TDS**	**Ratio TDS/Salt**	**Ratio EC/Salt**
Bean Green	4,8	6,38	2,53	3,55	2,89	-0,017	0,75	0,71	1,23	0,88
Beetroot Red	9,1	5,30	8,93	8,26	6,90	0,097	1,72	1,08	1,20	1,29
Cabbage	5,4	6,08	5,16	3,45	2,81	-0,003	0,89	1,50	1,23	1,84
Carrot	9,1	6,10	7,94	5,40	4,44	0,108	1,49	1,47	1,22	1,79
Celery leaves	6,2	5,87	1,65	1,11	0,96	0,007	1,06	1,49	1,15	1,72
Celery stem	3,1	5,85	1,62	8,07	7,95	0,238	0,53	0,20	1,02	0,20
Celery root	7,1	6,32	8,98	6,01	5,03	-0,007	1,12	1,49	1,19	1,79
Corn	10,0	6,70	2,93	1,96	1,53	-0,017	1,49	1,49	1,28	1,92
Eggplant	5,0	5,16	4,54	3,04	2,46	-0,003	0,97	1,49	1,24	1,85
Onion	7,3	5,68	3,35	2,24	1,78	0,030	1,29	1,50	1,26	1,88
Pepper Green	4,8	6,14	4,80	2,70	2,22	-0,140	0,78	1,78	1,22	2,16
Potato	6,3	4,69	0,87	0,59	0,49	0,020	1,34	1,49	1,20	1,79
Spinach	3,9	6,35	8,94	4,84	5,10	0,188	0,61	1,85	0,95	1,75
Tomato Green	4,5	4,51	4,41	2,96	2,39	0,049	1,00	1,49	1,24	1,85
Tomato Red	5,4	4,37	3,89	2,61	2,10	0,114	1,24	1,49	1,24	1,85
Zucchini	3,5	6,22	4,52	3,03	2,45	0,017	0,56	1,49	1,24	1,84
Average for Vegetables	***6,1***	***5,72***	***270***	***182***	***147***	***0,05***	***1,07***	***1,38***	***1,20***	***1,66***

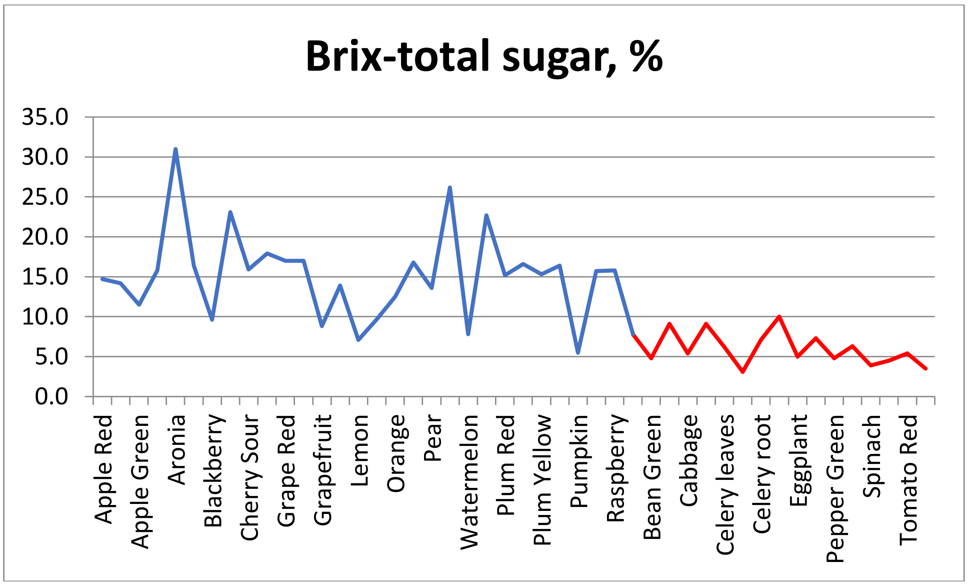
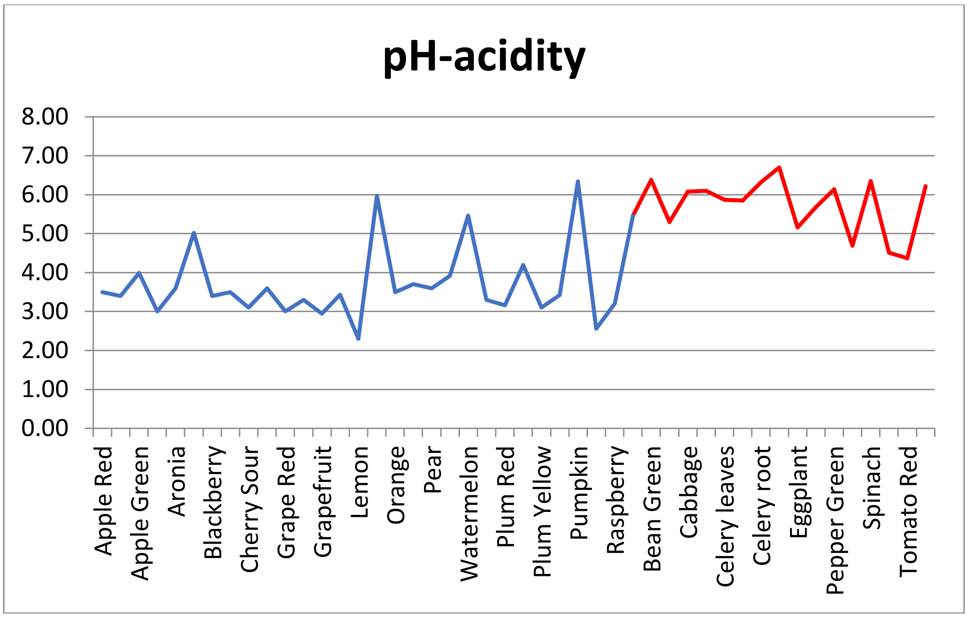


Fig. 1 Total sugar content by Brix (%) of the juices (blue line for fruits, red line for vegetables)



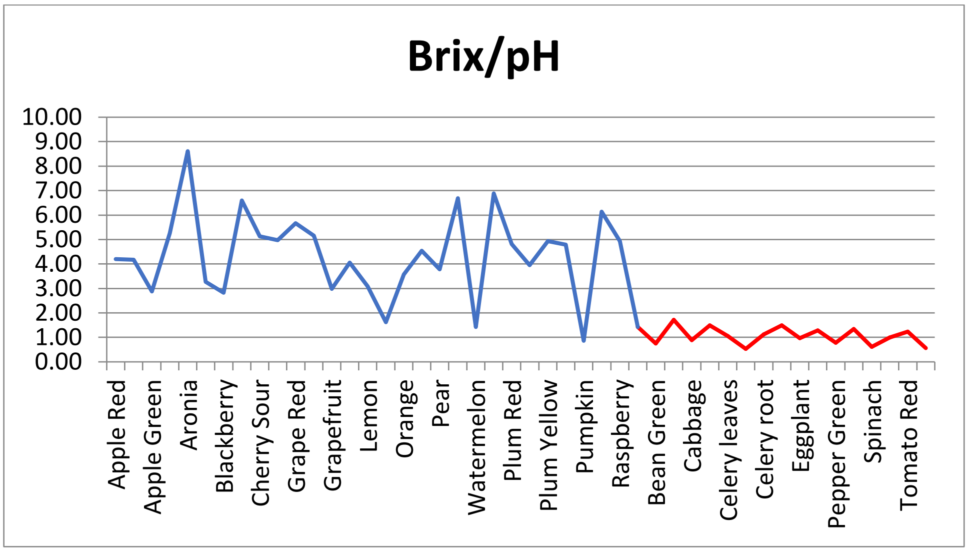
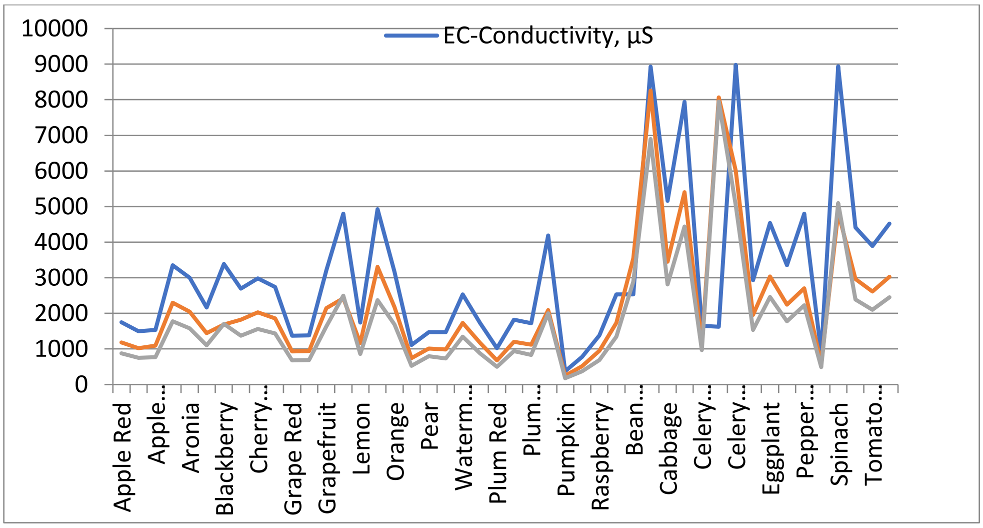


Fig. 3 Ratio Brix/pH (blue line for fruits, red line for vegetables)



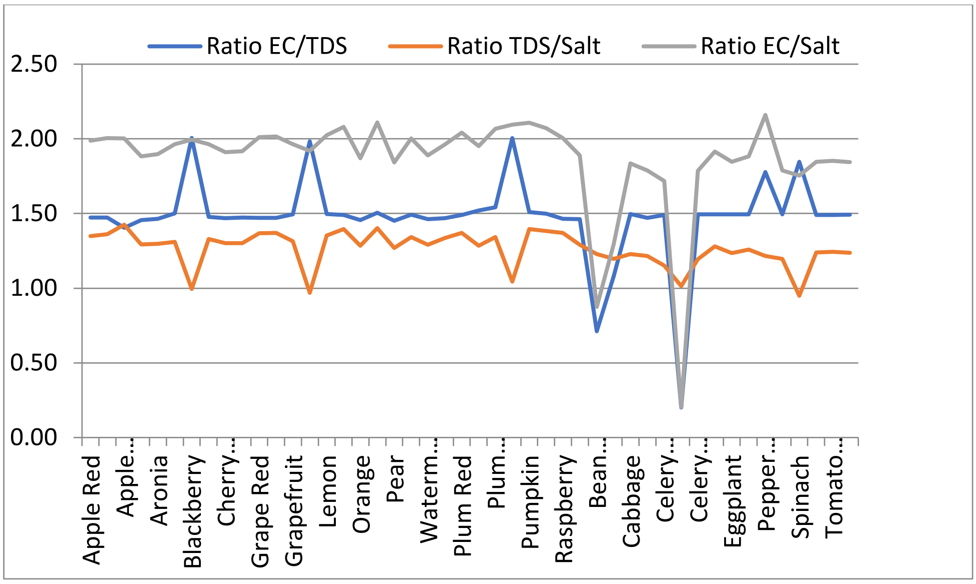


Fig. 5 Ratios EC/TDS, Ratio TDS/Salt are in vice version relation with, but Ratio EC/Salt relates with Ratio EC/TDS.

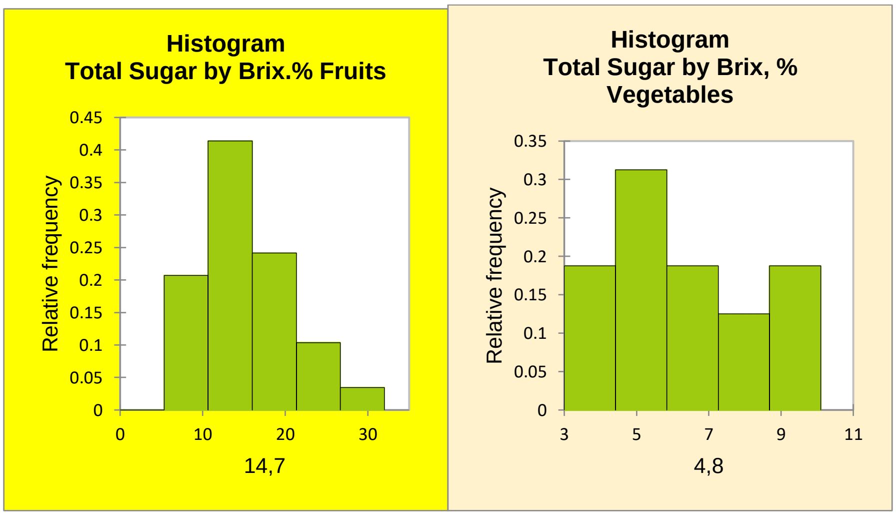


Fig. 6 Histograms of the measurement results of Toal Sugar Content (%) in fruits compared with vegetables.

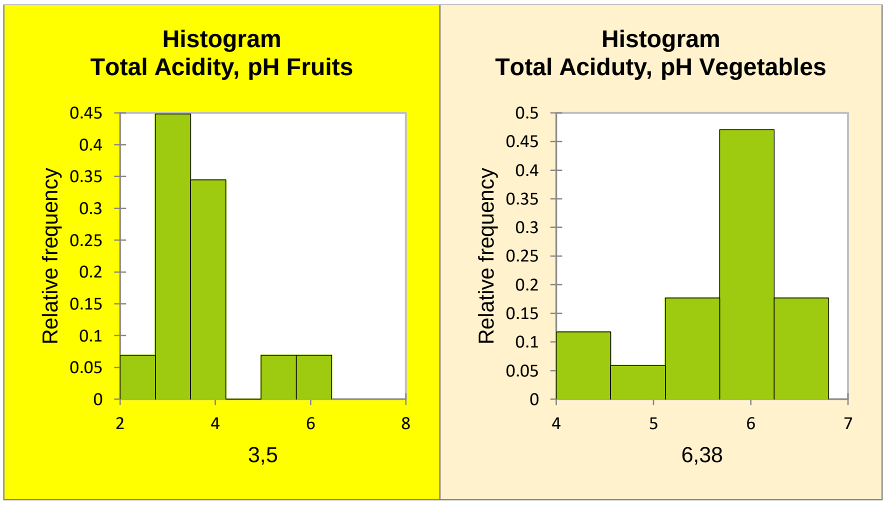


Fig. 7 Histograms of the measurement results of Toal Acidity (pH) in fruits compared with vegetables.

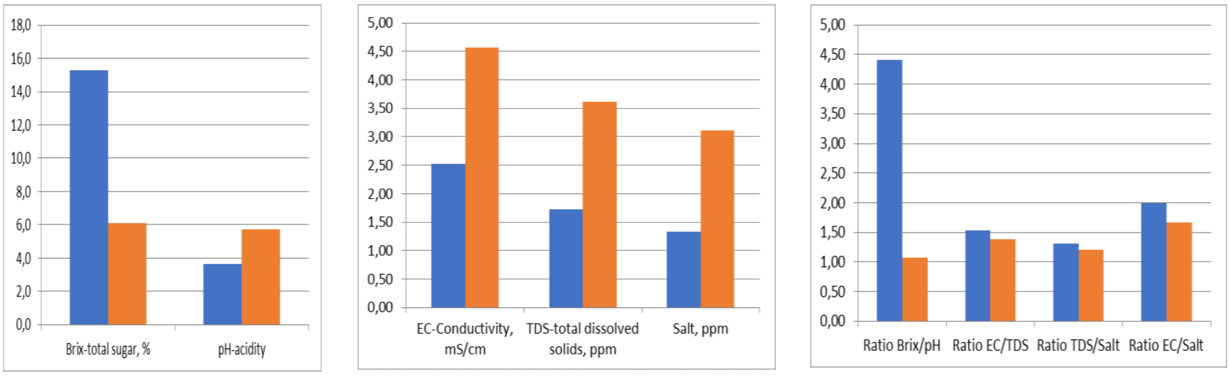


Fig. 8 Technological parameters of fruits in blue and vegetables in orange.

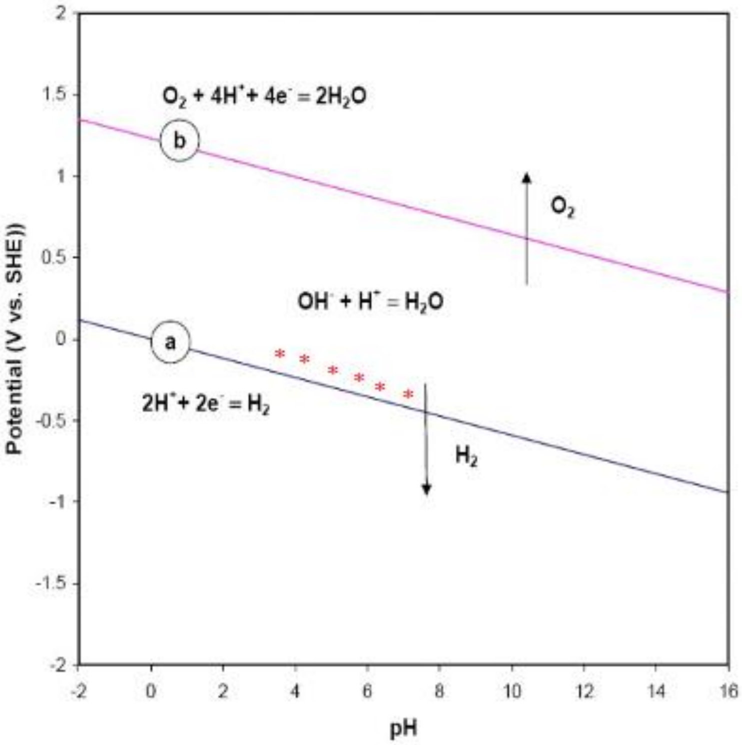


Fig. 9 **-Location of all studied juices (purees) at Eh-pH water diagram (Sotirov et al. 2022).

Table 3 Agglomerative hierarchical clustering (AHC) Similarity, Summary statistics:

Variable	Observations	Obs. with missing	Obs. without	Minimum	Maximum	Mean	Std. deviation
X1	46	0	46	3,100	31,000	11,891	6,384
X2	46	0	46	2,300	6,700	4,428	1,306
X3	46	0	46	0,373	8,980	3,106	2,151
X4	46	0	46	0,247	8,260	2,251	1,776
X5	46	0	46	0,177	7,950	1,869	1,637
X6	46	0	46	0,530	8,611	3,176	2,124
X7	46	0	46	-0,140	0,335	0,085	0,093
X8	46	0	46	0,530	8,611	3,176	2,124
X9	46	0	46	0,201	2,006	1,477	0,276
X10	46	0	46	0,949	1,425	1,266	0,116
X11	46	0	46	0,204	2,160	1,866	0,326

Table 4 Agglomerative hierarchical clustering (AHC) Similarity, Correlation matrix:

from \ to	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1	-0,635	-0,354	-0,425	-0,434	0,957	0,270	0,957	0,177	0,384	0,364
X2	-0,635	1	0,474	0,523	0,509	-0,800	-0,435	-0,800	-0,236	-0,317	-0,383
X3	-0,354	0,474	1	0,765	0,735	-0,421	0,018	-0,421	0,158	-0,521	-0,150
X4	-0,425	0,523	0,765	1	0,989	-0,480	0,086	-0,480	-0,457	-0,532	-0,699
X5	-0,434	0,509	0,735	0,989	1	-0,478	0,152	-0,478	-0,443	-0,615	-0,730
X6	0,957	-0,800	-0,421	-0,480	-0,478	1	0,358	1,000	0,188	0,391	0,379
X7	0,270	-0,435	0,018	0,086	0,152	0,358	1	0,358	0,115	-0,389	-0,111
X8	0,957	-0,800	-0,421	-0,480	-0,478	1,000	0,358	1	0,188	0,391	0,379
X9	0,177	-0,236	0,158	-0,457	-0,443	0,188	0,115	0,188	1	-0,117	0,839
X10	0,384	-0,317	-0,521	-0,532	-0,615	0,391	-0,389	0,391	-0,117	1	0,437
X11	0,364	-0,383	-0,150	-0,699	-0,730	0,379	-0,111	0,379	0,839	0,437	1

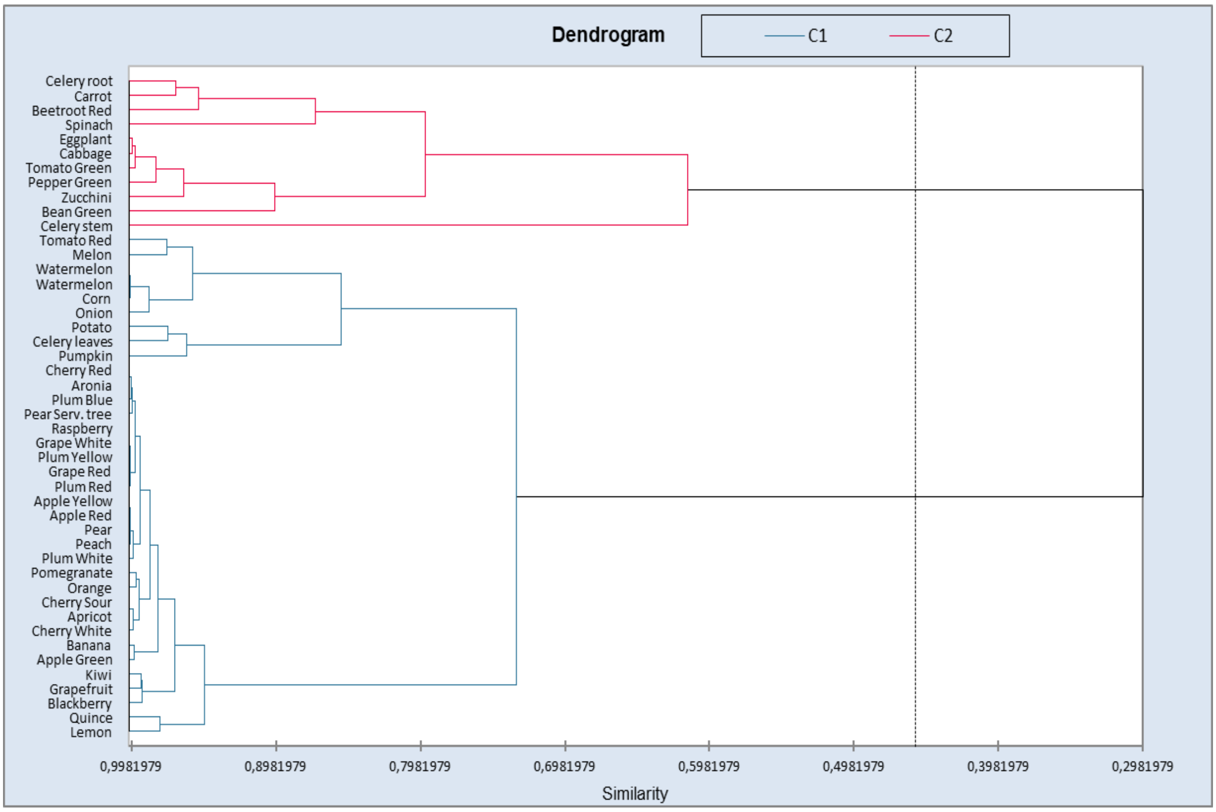


Fig. 10 Agglomerative hierarchical clustering (AHC) Similarity / Coefficient of correlation is 0, 40; Number of clusters = 2:

Table 5 Agglomerative hierarchical clustering (AHC) Similarity, Summary statistics:

Variable	Observations	Obs. with missing	Obs. without	Minimum	Maximum	Mean	Std. deviation
X1	46	0	46	3,100	31,000	11,891	6,384
X2	46	0	46	2,300	6,700	4,428	1,306
X3	46	0	46	0,373	8,980	3,106	2,151
X4	46	0	46	0,247	8,260	2,251	1,776
X5	46	0	46	0,177	7,950	1,869	1,637
X6	46	0	46	0,530	8,611	3,176	2,124
X7	46	0	46	-0,140	0,335	0,085	0,093
X8	46	0	46	0,530	8,611	3,176	2,124
X9	46	0	46	0,201	2,006	1,477	0,276
X10	46	0	46	0,949	1,425	1,266	0,116
X11	46	0	46	0,204	2,160	1,866	0,326

Table 6 Agglomerative hierarchical clustering (AHC) Similarity, Correlation matrix:

from \ to	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	1	-0,635	-0,354	-0,425	-0,434	0,957	0,270	0,957	0,177	0,384	0,364
X2	-0,635	1	0,474	0,523	0,509	-0,800	-0,435	-0,800	-0,236	-0,317	-0,383
X3	-0,354	0,474	1	0,765	0,735	-0,421	0,018	-0,421	0,158	-0,521	-0,150
X4	-0,425	0,523	0,765	1	0,989	-0,480	0,086	-0,480	-0,457	-0,532	-0,699
X5	-0,434	0,509	0,735	0,989	1	-0,478	0,152	-0,478	-0,443	-0,615	-0,730
X6	0,957	-0,800	-0,421	-0,480	-0,478	1	0,358	1,000	0,188	0,391	0,379
X7	0,270	-0,435	0,018	0,086	0,152	0,358	1	0,358	0,115	-0,389	-0,111
X8	0,957	-0,800	-0,421	-0,480	-0,478	1,000	0,358	1	0,188	0,391	0,379
X9	0,177	-0,236	0,158	-0,457	-0,443	0,188	0,115	0,188	1	-0,117	0,839
X10	0,384	-0,317	-0,521	-0,532	-0,615	0,391	-0,389	0,391	-0,117	1	0,437
X11	0,364	-0,383	-0,150	-0,699	-0,730	0,379	-0,111	0,379	0,839	0,437	1

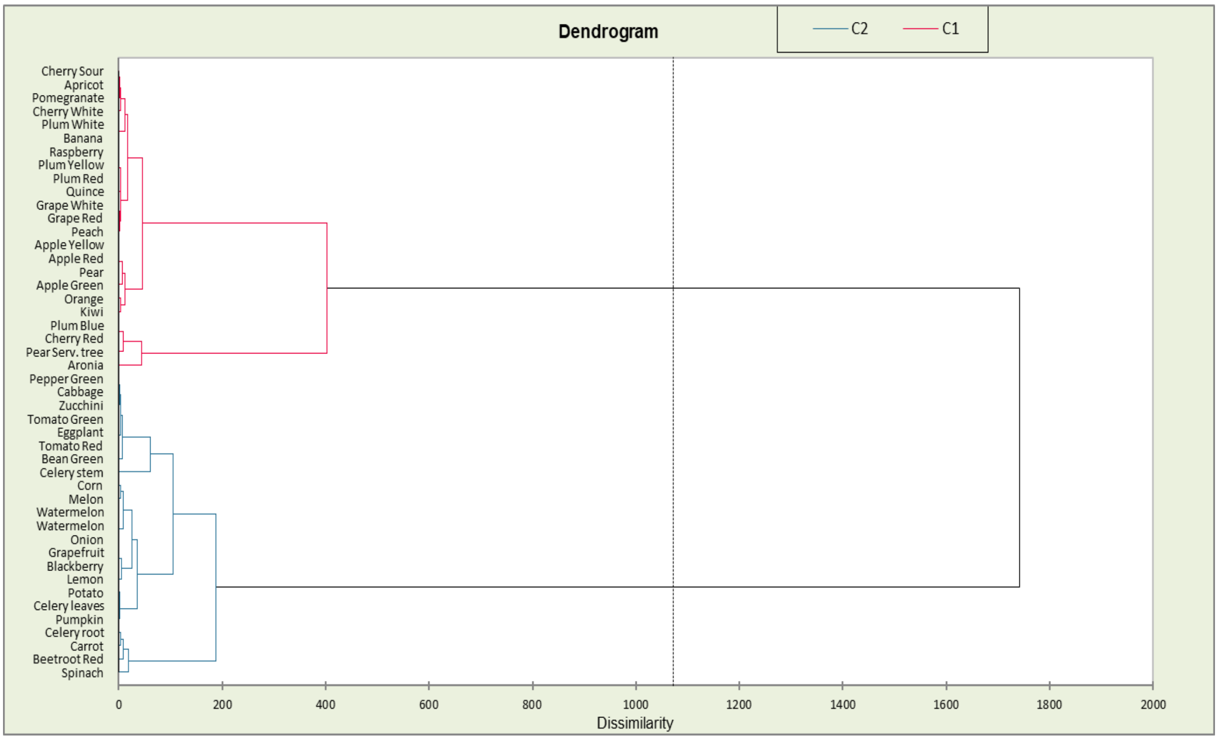


Fig. 11 Agglomerative hierarchical clustering (AHC)-dissimilarity / Coefficient of correlation is 1075; Number of clusters = 2:

Conclusions

In conclusion, it can be said that the statistical approach in the analysis of data obtained when measuring technological parameters of fruit and vegetable juices in the food-processing industry are extremely valuable. The comparison of the charts and tables from a cluster analysis show hidden information for the ordinary eye. The unification of different types of fruits and vegetables by similarities of their technological and organo-leptic indicators makes it possible to replace the different types of raw material or replace them by varieties so that they fit technologically and organo-leptically each other. In the absence of supplies of certain fruits and vegetables, substitutes can be selected, new recipes for mixing individual fruits and vegetables can be developed to achieve excellent nutritional and technological qualities of the juice. When comparing data on similarities and dissimilarities, we see what can be expected when mixing and which fruits and vegetables can be technologically substituted. The statistical approach allows us to save others in vain experiments to create recipes of products. It gives us an orientation on some food safety hazards. It saves millions of euros for the use of interchangeable raw materials.

REFERENCES:

1. Bulgarian State Gazette No 100 (2013). Ordinance on the requirements for fruit juices.
2. Dahl T, Naes T. Outlier and group detection in sensory panels using hierarchical cluster analysis with the procrustes distance. Food Quality and Preference, Barking, v. 15, n. 3, 195-208, 2004.
3. Decree No 217 of 29 July 2022 adopting an Ordinance on the requirements for fruit juices and certain similar
4. products intended for human consumption.

5. Henrique PS, Mota AR; Maia GA; Brito ES; Garruti DS; Figueiredo RW. Comparison of acceptability of tropical fruit mixed nectars by mean test and multivariate statistical analysisCincias Agrarias, Londrina, v. 34, n. 5, p. 2307-2316, set./out. 2013, DOI: 10.5433/1679-0359.2013v34n5p2307; ISSN: 1676-546X
6. Johnson RA, Wichern DW. Applied multivariate statistical analysis. 5th ed. Prentice Hall: Englewood Cliffs, 2002, 767 p.
7. Qannari EM, Vigneau E, Luscan P, Lefebvre AC, Vey F. Clustering of variables, application in consumer and sensory studies. Food Quality and Preference, Barking, v. 8, n. 5,6, p. 423-428, 1997.
8. Simunaniemi AM, Nydahl M, Andersson A. Cluster analysis of fruit and vegetable-related perceptions: an alternative approach of consumer segmentation. J Hum Nutr Diet. 2013 Feb;26(1):38-47. doi: 10.1111/j.1365-277X.2012.01272 x. Epub, 2012 Jul 31. PMID: 23339430
9. Sotirov, A., N. Glavev, D. Sotirov, S. Dimitrova, N. Pistalov, V. Sotirov, K. Sotirov (2021). Agro-ecological and
10. technological quality of some apples, WSEAS Transactions on Environment and Development, Vol. 17, 56-65.
11. Sotirov, A., S. Dimitrova, D. Sotirov, Zhelyazkov, P. (2022). Application of the Eh-pH water diagram for fruit
12. juices and its utilization in the foodtechnology. Scientific conference "Ecology and Agrotechnologies-Fundamental science and practical implementation", Agricultural Academy, Sofia, Bulgaria, 5-6 December.
13. Ward JH. Hierarchical grouping to optimize an objective function. Journal of the American Statistical Association, New York, v. 58, n. 301, p. 236-244, 1963.
14. XLSTAT - PRO. User’s guide. Addinsoft, New York, USA, Version 7.5. 2005. p. 1-104.
15. Ying Li, Jaspreet A, Bahadur R, Pehrsson P. Cluster Analysis of Micronutrients in Raw and Minimally Processe, Plant Foods (P24-049-19). Current Developments in Nutrition, Volume 3, Supplement 1, 2019, nzz044.P24-049-19, ISSN 2475-2991, https://doi.org/10.1093/cdn/nzz044.P24-049-19