BioFlux ProEnvironment **Original Article**

ProEnvironment 16/54 (2023) 102 - 109

Testing the Environmental Influence on Fruit Wastes Nutritional Content

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Received 19 April 2023; received and revised form 23 May 2023; accepted 26 May 2023; Available online 30 June 2023

Abstract

New methods for the use of fruit waste are becoming more prevalent in efforts to reduce the environmental footprint associated with apple, pear, and plum waste. The aim of the present research is to emphasize by using exploratory statistical approaches the major components of fruits wastes, and potential interaction between the environmental factors and nutritional content of apple, pear, and plum waste, respectively. The studied interactions are emphasized using statistical processing. The cluster analysis shows that the major nutritional components are nitrogen-free matters and crud fiber, while concerning mineral and vitamin C contents, potassium and phosphorus are identified as minerals with highest occurrence. In all analyzed fruit wastes were identified four factors, but with different contributions to variability function of fruit species. In apple and pear wastes, the PCA shows that temperature positively influences the nutritional content, while precipitation regimen has different influence on crude chemical composition function of species. In plum wastes, the crude chemical composition is positively correlated only with temperature regimen, the mineral and vitamin c contents are not influenced by environmental factors.

Keywords: cluster analysis, exploratory analysis, factors, principal component analysis.

1. Introduction

Innovative approaches for valorization of fruit wastes, such as anaerobic digestion, enzymatic processing, and waste valorization technologies are increasingly being employed to mitigate the environmental impact of apple, plum, and pear waste. These strategies aim to maximize resource recovery, minimize landfill burden, and foster circular economy principles by transforming waste into value-added products and energy sources.

Moreover, public awareness campaigns and policy initiatives promoting waste reduction, recycling, and sustainable consumption play pivotal roles in addressing the challenges associated with fruit waste management [1, 4, 9, 10, 11].

Byproducts based on apple, pear, and plum wastes can be utilized in composting, livestock feed, or as raw materials for different uses. For example, apple wastes, due to pectin extraction may be used as dietary fiber supplements, plums byproducts can serve as ingredients for animal feed or organic fertilizers, while pear wastes may be used for composting, as animal feed, in the formulation of functional foods, dietary supplements, or fermented products like vinegar [2, 5, 6].

The nutritional content of fruit wastes as apple, pear or plum wastes, is influenced by a variety of environmental factors that encompass growing conditions, post-harvest handling, processing techniques, and storage methods. Understanding these influences is crucial for optimizing the nutritional value and sustainability of fruit waste utilization. Implementing sustainable agricultural practices, optimized processing techniques, and efficient waste management strategies can help preserve the nutritional integrity of fruit wastes and maximize their potential for value-added utilization in food, feed, and other applications [2, 3, 6, 10, 11].

The aim of the present research is to emphasize by using exploratory statistical approaches (cluster analysis and principal components analysis – PCA) the major components of fruits wastes, and potential interaction between the environmental temperature, rainfall regimen, and wind velocity and nutritional content of three fruits species, apple, pear, and plum waste, respectively.

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2. Material and Method

The interaction between environmental temperature, rainfall regimen and wind velocity and nutritional composition of waste collected from three fruit species (apple, plum and pear) is emphasized using statistical processing.

The fruit wastes were harvested from two counties located in Transylvania, Cluj and Bistrița-Năsăud, respectively.

The environmental parameters, which characterize the experimental area are represented by means expressed by the year 2023: 12.8 °C, 56.34 mm (which corresponds to the year precipitations sum of 426.64 mm), and 5.76 m/s (Table 1).

Table 1. The climatic parameters of the experimental area

Parameter	N	X	Sum	s	CV, %
Temperature, t (°C)	5	12.85	-	1.09	8.49
Precipitations, pp (mm)	5	56.34	426.64	17.41	9.86
Wind velocity, v (m/s)	5	5.76	-	0.57	9.86

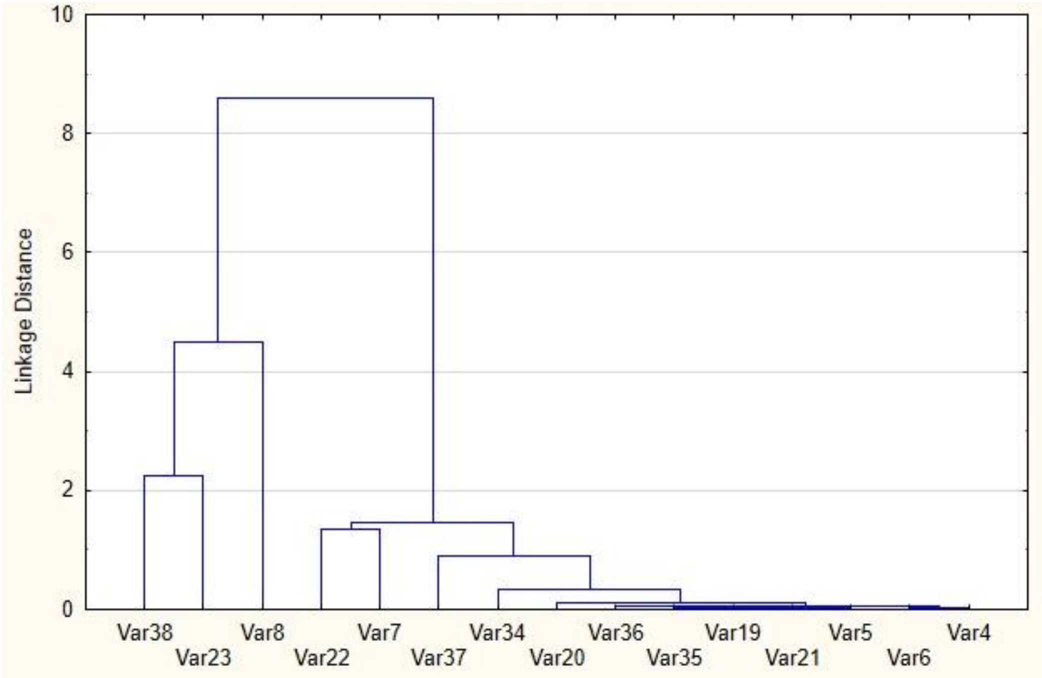
The factorial and cluster analyses were implemented for showing the interaction between the mentioned environmental factors (temperature, rainfall regimen, and wind velocity) and crude chemical content (protein CP, fat CF, fiber CFi, ash CA, nitrogen-free matter NFM), vitamin C, and minerals (calcium Ca, magnesium Mg, phosphorus P, potassium K, and iron Fe) of apple, pear, and plum wastes. In this respect, STATISTICA v.8.0 for windows was used, with option exploratory analysis. The Kaiser–Maier–Olkin (KMO) test for sampling adequacy and Bartlett probes were used to verify the validity of implementing PCA [7].

3. Results and Discussions

According to cluster analysis concerning the crude chemical composition of the three fruit species wastes, we obtain two principal clusters, both ramified. The first cluster, which includes the highest linkage distances corresponds to the highest means of crude chemical composition represented by the nitrogen-free matter quantified in all three fruit species. It is divided in two subclusters, one with two branches corresponding to pear and plum wastes, and the other, which is the highest, to apple wastes. The second cluster has two principal branches located at a much lower linkage distance compared to the first cluster.

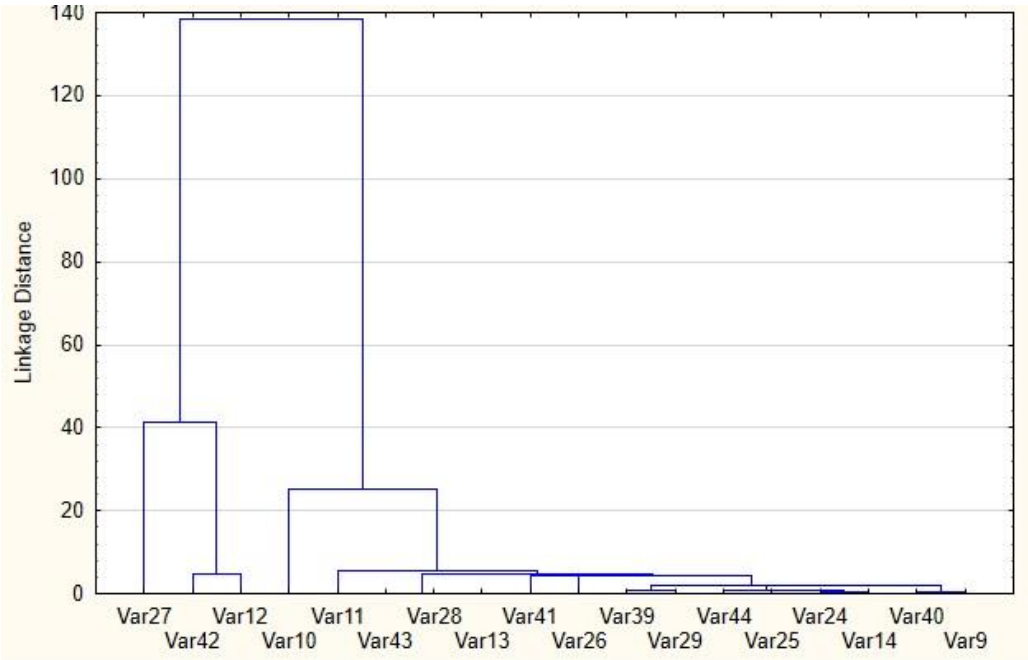
One branch corresponds to subclusters located at the highest linkage distance of the subcluster and includes crude fiber content quantified in apple and pear wastes. The other is made of one cluster representing crude fiber content quantified in plum wastes, while the other at its turn is made of ten subclusters located at very low linkage distance, which suggests that they are present in low concentrations. Thus, results that the major nutritional components of all three fruit species wastes are represented by nitrogen-free matters and crud fiber (Fig. 1).

The cluster analysis applied to mineral and vitamin C contents of apple, pear, and plum wastes shows the presence of two principal clusters. The first cluster, divided in two subclusters, corresponds to the highest linkage distances, which represent the K content identified in all three fruit wastes. On of the subclusters is represented by a single branch corresponding to the highest K content identified in pear wastes, and the other by two branches corresponding to K contents quantified in apple and plum wastes. The second cluster has two principal branches. One branch corresponds to a single subcluster that represents Mg content of apple wastes, while the other has a high number of branches, of which those corresponding to P content are located at the highest linkage distance. The graphic representation of the cluster analysis shows that potassium and phosphorus are identified as minerals with highest occurrence in apple, pear, and plum wastes (Fig. 2).



Apple wastes: Var 4-CP; Var 5-CF; Var 6-CA; Var 7-CFi; Var 8-NFM; Pear wastes: Var 19-CP; Var 20-CF; Var 21-CA; Var 22-CFi; Var 23-NFM; Plum wastes: Var 34-CP; Var 35-CF; Var 36-CA; Var 37-CFi; Var 38-NFM.

Figure 1. The cluster analysis concerning the crude chemical composition of apple, pear, and plum wastes



Apple wastes: Var 9-Ca; Var 10-Mg; Var 11-P; Var 12-K; Var 13-Fe; Var 14- Vitamin C; Pear wastes: Var 24-Ca Var-Mg; 25 Var 26-P; Var 27-K; Var 28-Fe Var 29 Var-Vitamin C; Plum wastes: 39-Ca; Var 40-Mg; Var 41-P; Var 42-K; Var 43-Fe: Var 44 -Vitamin C.

Figure 2. The cluster analysis concerning the minerals, and vitamin C composition of apple, pear, and plum wastes

Because according to Bartlett test $p < 0.05$, and the and KMO value > 0.5, we conclude that applying PCA in our study is appropriate for all analyzed fruit wastes. In apple, we identified four factors, Factor 1 – Crude chemical content that is responsible of 44.979 % of variance, Factor 2 – Minerals and vitamin C that are responsible of 31.374 % of variance, Factor 3 – Environmental parameters that are responsible of 14.961 % of variance, and Factor 4 – Species that is responsible of 8.686 % of variance (Table 2).

The projection of the variables in principal components (PC) plans according to each factor identified in apple shows factor specific influences (Table 3, Fig. 3).

In Plans **1 and 2** representation, Factor 1 – Crude chemical content is positively influenced by CP, CA, Ca, Mg, and P, while Factor 2 – Minerals and vitamin C, by CFi, Ca, Mg, and temperature regimen. In Plans **1 and 3** representation, Factor 1 – Crude chemical content is positively influenced by CF, CFi, NFM, Ca, Mg, P, K, Fe and temperature regimen while Factor 3 – Environmental parameters, by CFi, Ca, Mg, and temperature regimen. In Plans **1 and 4** representation, Factor 1 – Crude chemical content is positively influenced by CP, CA, NFM, Ca, Mg, Fe and precipitation regimen while Factor 3 – Environmental parameters, by CFi, Ca, Mg, and temperature regimen.

Table 2. The Eigenvalues identified within PCA applied to plum wastes

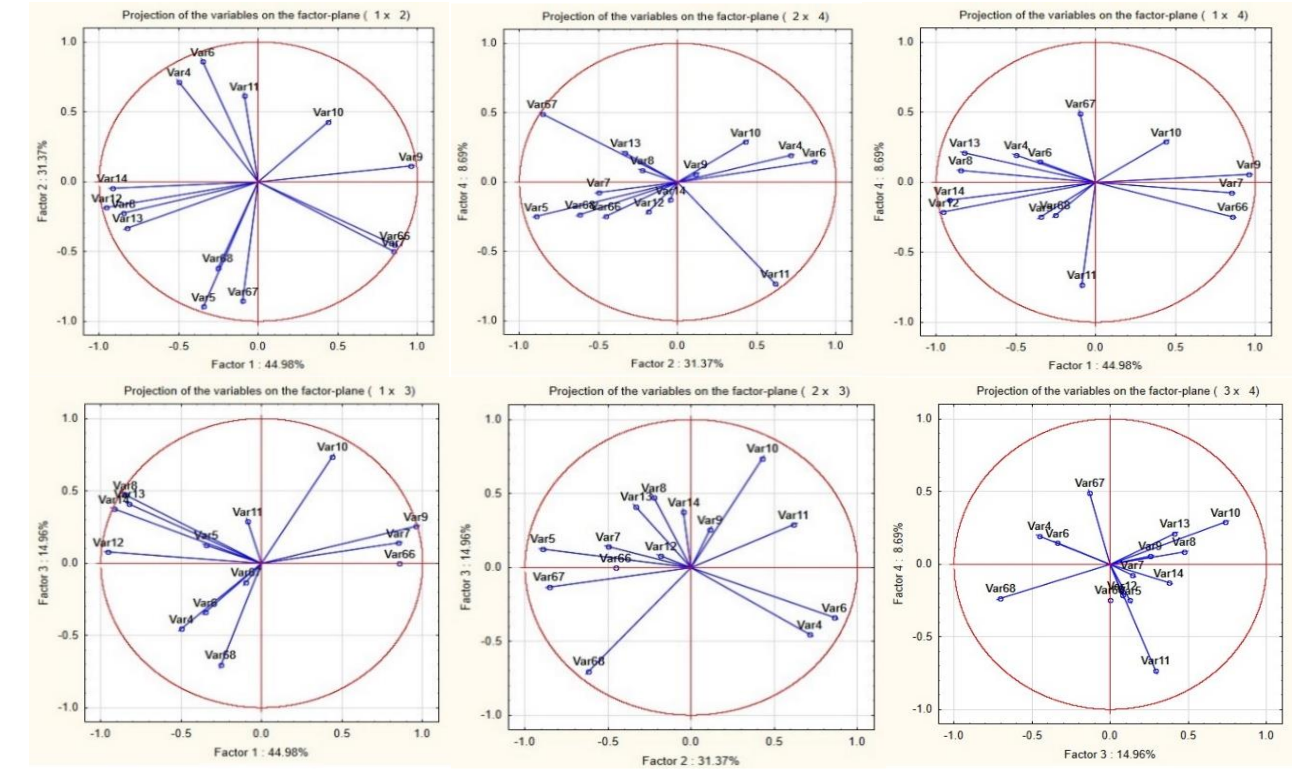
Factors	Eigenvalue	% Total	Cumulative	Cumulative, %
Factor 1	6.297	44.979	6.297	44.979
Factor 2	4.392	31.374	10.689	76.353
Factor 3	2.094	14.961	12.784	91.314
Factor 4	1.216	8.686	14.000	100.000

In Plans **2 and 3** representation, Factor 2 – Minerals and vitamin C is positively influenced by CF, CFi, NFM, Ca, Mg, P, K, Fe, vitamin C, and temperature regimen while Factor 3 – Environmental parameters, by CP, CA, Ca, Mg, and P. In Plans **2 and 4** representation, Factor 2 – Minerals and vitamin C is positively influenced by CP, CA, NFM, Ca, Mg, Fe and precipitation regimen while Factor 4 – Species, by CP, CA, Ca, Mg, and P. In Plans **3 and 4** representation, Factor 3 – Environmental factors is positively influenced by CP, CA, CFi, NFM, Ca, Mg, Fe and precipitation regimen while Factor 4 – Species, by CF, CFi, NFM, Ca, Mg, P, K, Fe, vitamin C, and temperature regimen. In apple wastes, the PCA shows that whatever principal factors, the highest influences upon them are exercised by the following nutritional components: fiber, nitrogen-free matter, Ca, and Mg.

Among environmental factors, temperature positively influences the nutritional content, while precipitation regimen has different influence on crude chemical composition function of species (Fig. 3).

Table 3. The Factor coordinates of the variables within PCA applied to plum wastes

Factors	Factor 1- Crude chemical content	Factor 2 – Mineral and vitamin C content	Factor 3 – Environmental parameters	Factor 4 – Species
CP (g/100 g)	-0.499	0.713	-0.454	0.195
CF (g/100 g)	-0.345	-0.896	0.126	-0.248
CA (g/100 g)	-0.352	0.860	-0.340	0.145
Cfi (g/100 g)	0.851	-0.501	0.138	-0.075
NFM (g/100 g)	-0.849	-0.225	0.471	0.084
Ca (g/100 g)	0.959	0.112	0.254	0.056
Mg (g/100 g)	0.438	0.427	0.736	0.288
P (g/100 g)	-0.089	0.612	0.288	-0.731
K(g/100 g)	-0.956	-0.185	0.075	-0.214
Fe (g/100 g)	-0.823	-0.332	0.410	0.210
Vitamin C (g/100 g)	-0.918	-0.046	0.372	-0.129
t (°C)	0.856	-0.456	-0.003	-0.245
Pp (mm)	-0.097	-0.856	-0.133	0.490
v (m/s)	-0.255	-0.619	-0.705	-0.236



Var 4-CP; Var 5-CF; Var 6-CA; Var 7-CFi; Var 8-NFM; Var 9-Ca; Var 10-Mg; Var 11-P; Var 12-K; Var 13-Fe; Var 14- Vitamin C; Var 67- rainfall regimen (mm); Var 67- wind velocity (m/s).

Figure 3. The projections of the variables on the factors plans within PCA applied to apple wastes

In pear wastes, even though we identified four factors, only the first three of them Factor 1 – Crude chemical content that is responsible of 62.753 % of variance, Factor 2 – Minerals and vitamin C that are responsible of 23.558 % of variance, and Factor 3 – Environmental parameters that are responsible of 8.627 % of variance are considered in the study. Because Factor 4 – Species corresponds a sub unitarian Eigenvalue (0.709) it is not considered (Table 4).

Table 4. The Eigenvalues identified within PCA applied to plum wastes

Factors	Eigenvalue	% Total	Cumulative	Cumulative, %
Factor 1	8.785	62.753	8.785	62.753
Factor 2	3.298	23.558	12.084	86.311
Factor 3	1.208	8.627	13.291	94.938
Factor 4	0.709	5.062	14.000	100.000

The projections of the variables in principal components (PC) plans according to all three factors considered in pear wastes are discussed (Table 5, Fig. 4).

In Plans **1 and 2** representation, Factor 1 – Crude chemical content is positively influenced by NFM, Ca, and Mg, while Factor 2 – Minerals and vitamin C, by CP, CF, CA, CFi, NFM, Ca, Mg, P, K, vitamin C, and wind velocity.

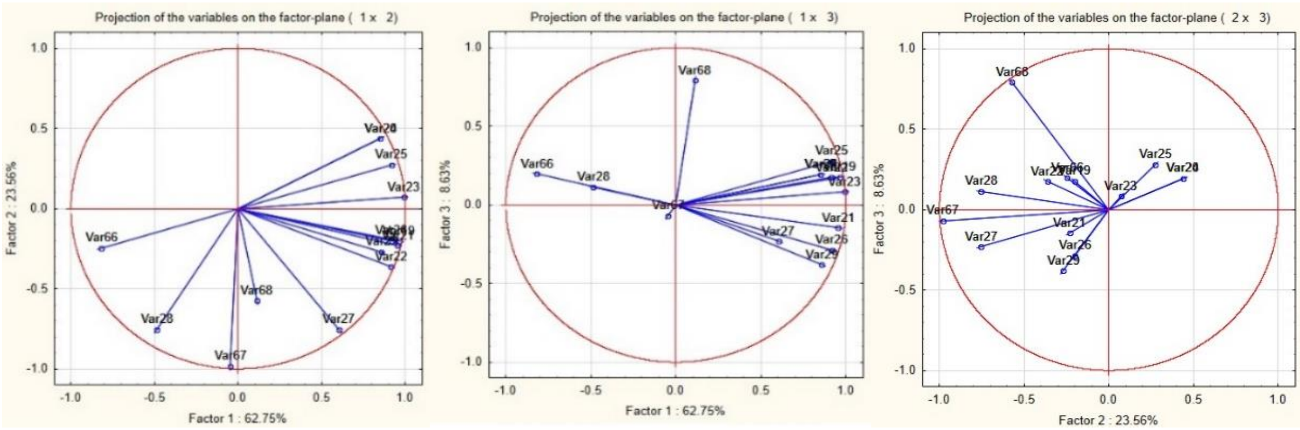
In Plans **1 and 3** representation, Factor 1 – Crude chemical content is positively influenced by CP, CF, CFi, NFM, Ca, Mg, Fe, wind velocity and temperature regimen, while Factor 2 – Minerals and vitamin C, by CP, CF, CFi, NFM, Ca, Mg, Fe, wind velocity and rainfall regimen. In Plans **2 and 3** representation, Factor 2 – Minerals and vitamin C is positively influenced by CP, CF, CFi, NFM, Ca, Mg, Fe, wind velocity and temperature regimen while Factor 3 – Environmental parameters, by CFi, NFM, Ca, and Mg.

In pear wastes, according to PCA, Factor 1, the crude chemical composition, respectively is positively correlated with wind velocity, and majority of nutrients, except Fe. Factor 2, Minerals, and vitamin C contents are positively correlated with NFM, Ca, Mg, and P. Factor 3 is positively correlated with temperature regimen, wind velocity, and also with the majority of nutrients, except crude ash, P, K, and vitamin C.

Among environmental factors, wind velocity has an influence on crude chemical composition (Fig. 4).

Table 5. The Factor coordinates of the variables within PCA applied to plum wastes

Factors/ Variables	Factor 1- Crude chemical content	Factor 2 – Mineral and vitamin C content	Factor 3 – Environmental parameters
CP (g/100 g)	0.109	-0.062	0.146
CF (g/100 g)	0.097	0.132	0.160
CA (g/100 g)	0.108	-0.070	-0.121
Cfi (g/100 g)	0.104	-0.110	0.145
NFM (g/100 g)	0.113	0.021	0.067
Ca (g/100 g)	0.097	0.132	0.160
Mg (g/100 g)	0.104	0.083	0.230
P (g/100 g)	0.104	-0.061	-0.238
K(g/100 g)	0.068	-0.229	-0.192
Fe (g/100 g)	-0.055	-0.229	0.094
Vitamin C (g/100 g)	0.097	-0.082	-0.316
t (°C)	-0.093	-0.075	0.163
Pp (mm)	-0.005	-0.298	-0.058
v (m/s)	0.013	-0.174	0.656



Var 19-CP; Var 20-CF; Var 21-CA; Var 22-CFi; Var 23-NFM; Var 24-Ca Var-Mg; 25 Var 26-P; Var 27-K; Var 28-Fe; Var 29 Var-Vitamin C; Var 67- rainfall regimen (mm); Var 67- wind velocity (m/s).

Figure 4. The projections of the variables on the factors plans within PCA applied to pear wastes

In plum wastes we also identified four principal factors, Factor 1 – Crude chemical content that is responsible of 69.023 % of variance, Factor 2 – Minerals and vitamin C that are responsible of 17.421 % of variance, and Factor 3 – Environmental parameters that are responsible of 9.569 % of variance. Similarly with situation emphasized when discussing pear wastes, only the first three of them are considered in the study. Because Factor 4 – Species corresponds a sub unitarian Eigenvalue (0.558) it is not considered (Table 6).

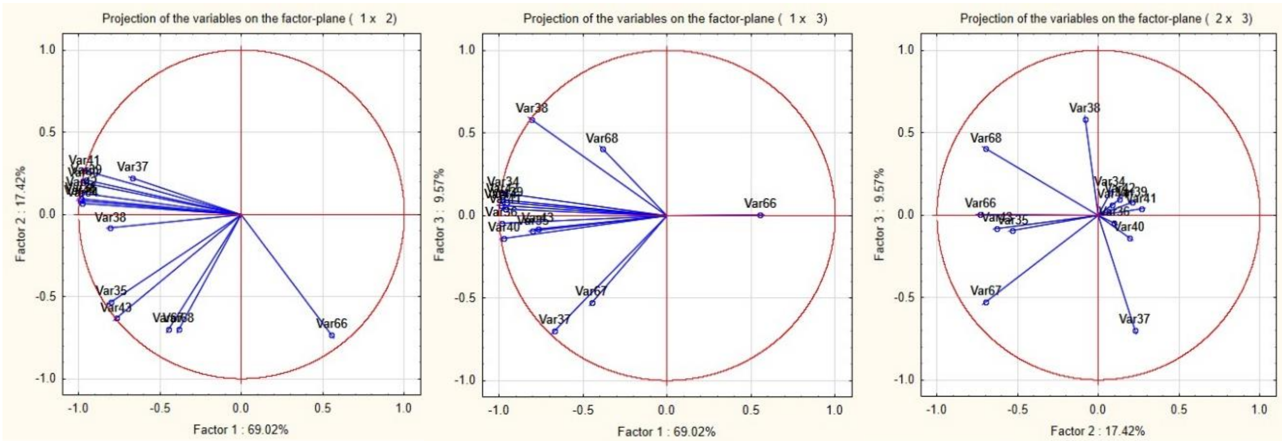
Table 6. The Eigenvalues identified within PCA applied to plum wastes

Factors	Eigenvalue	% Total	Cumulative	Cumulative, %
Factor 1	9.663	69.023	9.663	69.023
Factor 2	2.439	17.421	12.102	86.444
Factor 3	1.340	9.569	13.442	96.013
Factor 4	0.558	3.987	14.000	100.000

The projections of the variables in principal components (PC) plans according to all three factors considered in pear wastes are discussed (Table 7, Fig. 5). In Plans **1 and 2** representation, Factor 1 – Crude chemical content is correlated only with temperature regimen. Factor 2 – Minerals and vitamin C is not correlated with environmental factors, but positively correlated with majority of nutrients, except CF, NFM, and Fe. In Plans **1 and 3** representation, Factor 1 – Crude chemical content is also correlated only with temperature regimen. Factor 3 – Environmental parameters is positively correlated with wind velocity, and majority of nutrients, except CF, CFi, Mg, and Fe. In Plans **2 and 3** representation, Factor 2 – Minerals and vitamin C is not correlated with environmental factors, but positively correlated with majority of nutrients except CF, NFM, and Fe. Factor 3 – Environmental parameters is positively correlated with temperature and wind velocity, and with majority of nutrients, except by CF, CFi, Mg, and Fe.

Table 7. The Factor coordinates of the variables within PCA applied to plum wastes

Factors	Factor 1- Crude chemical content	Factor 2 – Mineral and vitamin C content	Factor 3 – Environmental parameters
CP (g/100 g)	-0.978	0.069	0.136
CF (g/100 g)	-0.801	-0.533	-0.094
CA (g/100 g)	-0.987	0.097	-0.047
Cfi (g/100 g)	-0.669	0.223	-0.698
NFM (g/100 g)	-0.808	-0.085	0.582
Ca (g/100 g)	-0.955	0.207	0.077
Mg (g/100 g)	-0.972	0.189	-0.137
P (g/100 g)	-0.964	0.265	0.035
K(g/100 g)	-0.984	0.130	0.096
Fe (g/100 g)	-0.769	-0.631	-0.080
Vitamin C (g/100 g)	-0.994	0.083	0.062
t (°C)	0.552	-0.733	0.005
Pp (mm)	-0.450	-0.697	-0.526
v (m/s)	-0.386	-0.699	0.402



Var 34-CP; Var 35-CF; Var 36-CA; Var 37-CFi; Var 38-NFM ; 39-Ca; Var 40-Mg; Var 41-P; Var 42-K; Var 43-Fe: Var 44 -Vitamin C; Var 66-temperature (°C); Var 67- rainfall regimen (mm); Var 67- wind velocity (m/s).

Figure 5. The projections of the variables on the factors plans within PCA applied to plum wastes

In plum wastes, according to PCA, Factor 1, the crude chemical composition is correlated only with temperature regimen. Factor 2, Minerals, and vitamin C contents is positively correlated with majority of nutrients, except CF, NFM, and Fe. Factor 3 is positively correlated with wind velocity, and majority of nutrients, except CF, CFi, Mg, and Fe (Fig. 5).

4. Conclusions

The cluster analysis applied to crude chemical composition and mineral and vitamin C content of studied fruit wastes emphasizes two principal clusters. Thus, our study shows that concerning crude chemical composition of apple, pear, and plum wastes, the major nutritional components are nitrogen-free matters and crud fiber, while concerning mineral and vitamin C contents, potassium and phosphorus are identified as minerals with highest occurrence.In all analyzed fruit wastes were identified four factors, but with different contributions to variability function of fruit species. In apple, Factor 1 – Crude chemical content that is responsible of 44.979 % for variance, Factor 2 – Minerals and vitamin C that are responsible for 31.374 % of variance, Factor 3 – Environmental parameters that are responsible for 14.961 % of variance, and Factor 4 – Species that is responsible of 8.686 % for variance. In pear and plum wastes even though we identified four factors, only the first three of them are considered in the study, because Factor 4 corresponds to sub unitarian

Eigenvalues. In pear wastes, Factor 1 is responsible for 62.753 % of variance, Factor 2 is for 23.558 % of variance, and Factor 3 for 8.627 % of variance are considered in the study. In plum wastes Factor 1 is responsible for 69.023 % of variance, Factor 2 for 17.421 % of variance, and Factor 3 of 9.569 % for variance.

According to PCA, in apple and pear wastes, whatever principal factors, the highest influences upon them are exercised by fiber, nitrogen-free matter, Ca, and Mg, while in plum wastes, Factors 2 and Factor 3 are correlated with most nutrients. Among environmental factors and nutritional content of fruits wastes are identified interrelationships.

Temperature positively influences the nutritional content, while precipitation regimen has different influence on crude chemical composition function of species in apple species, while in plum wastes, the crude chemical composition is correlated only with temperature regimen.

Acknowledgement: This article is funded by the Ministry of Agriculture, and Rural Development, through the Agency for Financing Rural Investments AFIR, National Program for Rural Development, Contract no. C161A0000011861300003/29.04.2021. Title of the project: "Valorization of the Pedological Variations for Efficient Obtaining of Innovative Fodder from tree Resources".

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