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The role of controlled and environmentally conditioned shade drying techniques on macro and microelement concentrations of commonly consumed fruit and vegetables

Ayşegül Korkmaz[1], Mehmet Musa Özcan[2*], Fatma Gökmen Yılmaz[1], Mustafa Mete Özcan[3]

[1]*Department of Soil Science and Plant Nutrition, Faculty of Agricultural, University of Selçuk, 42031, Konya-Turkey*
[2] *Faculty of Agriculture, Department of Food Engineering, University of Selçuk, 42031 Konya, Turkey*
[3] *Karapınar Aydoğanlar Vocatıonal School/Veterınary Medıcıne Department, University of Selçuk, 42031 Konya, Turkey*

**Corresponding author: mozcan@selcuk.edu.tr*

Abstract
Potassium amounts of shade dried fruits were specified to be between 6554.85 (red apple) and 22226.63 mg/kg (Green apple). Phosphorus quantities of shade dried fruits were determined between 628.82 (pear) and 2433.81 mg/kg (blueberry). In addition, among shade-dried fruits, the lowest and highest Mg were detected in red apple (237.37 mg/kg) and orange (1362.97 mg/kg), respectively. While the lowest and highest Cu contents of oven-dried fruits were detected in lime (1.64 mg/kg) and grape (6.42 mg/kg), the Cu contents of sun-dried fruits were 1.52 mg/kg (lime) and 6.41 mg/kg (blueberry) was assessed between. The Cu content of fruits dried in the shade was determined between 1.86 mg/kg (green apple) and 5.56 mg/kg (grape). In addition, the Zn contents of fruits dried in the oven were recorded between 0.89 mg/kg (red apple) and 6.48 mg/kg (lime), while the Zn contents of fruits dried in the sun were determined between 0.98 mg/kg (red apple) and 5.63 mg/kg (strawberry). While the lowest phosphorus was detected in green pepper, the P contents of other vegetables were higher than the K, Mg and Ca contents of the vegetables. K quantities of oven and sun dried vegetables were found to be between 18772.6 mg/kg (okra) and 45226.0 mg/kg (pumpkin) to 14745.8 mg/kg (okra) and 44137.9 mg/kg (pumpkin), respectively. The K amounts of shade-dried vegetables were found between 18353.5 (okra) and 48991.5 mg/kg (pumpkin). Fe contents of oven-dried vegetables were recorded between 27.50 mg/kg (tomato) and 94.98 mg/kg (pumpkin). Cu contents of vegetables were recorded to be low depending on the drying types. Depending on the drying types, the highest macro element contents in fruits were K, followed by P and Mg in decreasing order. Additionally, it has been observed that, in general, vegetables dried in the oven contain more Mn than vegetables dried in the sun and shade.

Keywords: fruits, vegetables, macro and micro elements, drying types, ICP-OES.

1. Introduction

Minerals required to maintain some physicochemical processes necessary for life are inorganic substances found in all body tissues and fluids [1]. Minerals, which play a vital role in overcoming the nutritional problem, are the essential nutrients of most foods [1]. The main purposes of drying are to preserve the food and extend its shelf life by reducing the water content and water activity of the food, to eliminate the use of expensive refrigeration systems for transportation and storage, to reduce space requirements for storage and transportation, to make the components that give different taste, flavor and aroma more concentrated [2-4]. Vegetables, which are a part of daily nutrition in many homes and constitute an important source of vitamins and minerals necessary for human health, are very rich sources of essential nutrients such as carotene, protein, vitamins, calcium, iron, ascorbic acid and visible mineral concentration [5]. Green leafy vegetables, which are rich in elements such as carotene, ascorbic acid, retinol, riboflavin, folic acid and calcium, iron, zinc, magnesium, manganese and selenium, have an important place among food products [6,7]. Plant foods contain indispensable

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components of human nutrition, providing the body with vitamins, protein, some hormone precursors and energy as well as necessary elements for well-being and health [8]. Vegetables are widely consumed as food because they provide sufficient amounts of vitamins, minerals and fiber [9-11]. Since there has recently been an increasing trend towards greater inclusion of green leafy vegetables in the human diet, some of the various green leafy vegetables available for human consumption are limited to a certain region [12]. As they make significant contributions to various metabolic functions in living cells, vegetables are an important source of macro minerals such as Ca, potassium, sodium and magnesium, as well as micro minerals such as Fe, copper, manganese, chromium and zinc [13-16]. Drying is the method in which water is removed from food by evaporation or sublimation, and is one of the many methods used in food preservation and is still widely used today. Thus, decomposition will be prevented by removing the water available for chemical, enzymatic or microbial degradation reactions. Factors affecting drying are drying speed, vapor pressure of the food and drying air, temperature and air speed, moisture diffusion in the product, thickness and surfaces exposed for drying [17-19]. The drying process refers to the process in which the water in the material evaporates due to heat and substance exchange between the product and the working environment in order to extend the shelf life of fresh fruits with high water content [20]. Hot air convection drying, freeze drying, microwave drying, solar drying, oven drying, spray drying and vacuum drying techniques are the most commonly applied drying methods in the food industry [21-24]. Although macro and micronutrient elements and bioactive compounds are more concentrated when drying foods, one of the physical effects frequently observed in dried fruit is the significant shrinkage of food structures and tissues [25]. Since most fruit and vegetables constitute a special source of essential nutrients necessary for human health, increased fruit consumption significantly reduces both chronic and malnutrition-related diseases such as diabetes and obesity [26]. Different fruits, such as wild fruit varieties, are excellent sources of essential minerals and have profound effects on human metabolism due to their different nutritional compositions and have a wide range of uses in human nutrition [27]. Sun drying of fruits in order to improve, preserve and add value to the storage period has been used since prehistoric times, despite the drawbacks such as long drying time, various contaminations, product deterioration and other undesirable damages [28-30]. The main purpose of this study was to reveal the changes in biogenic macro and micro element contents of different fruit (Grape, white cherry, red cherry, plum, pear, peach, green apple, red apple, strawberry, lemon, lime, orange, sour cherry and blueberry) and vegetables (Pumpkin, Eggplant, Tomatoes, Red pepper, Green pepper, Green bean, Okra) obtained from different locations as a result of drying in ovens, sun and shade.

2. Materials and method

2.1. Material

Fruit and vegetable samples were provided from Antalya, Konya and Mersin provinces in 2023. Before the analysis, the samples were washed with distilled water, and then the dried in a drying cabine, sun drying and shade place. HNO_3 and H_2O_2 are analytical grade and Merck company (Darmstadt, Germany).

2.2. Fruit Drying Process

Fresh fruit and vegetable samples were first washed with distilled water, then dried and sliced to a thickness of 2 mm. The samples were divided into three groups, each subjected to a different drying method: air-drying in a cabinet with air circulation at 70°C, sun-drying in open air, and shade-drying. These processes continued until the samples reached a stable weight, with moisture content reduced to 10-15%.

2.3. Elemental Analysis of Fruit Samples

For elemental analysis, 0.2 g of fruit and vegetable samples were digested in a microwave system at 210°C and 200 PSI using 5 mL of concentrated nitric acid (HNO_3) and 2 mL of hydrogen peroxide (H_2O_2, 30% w/v). The resulting solutions were diluted with deionized water to a final volume of 20 mL. Element concentrations in the samples were then measured using inductively coupled plasma optical emission spectrometry (ICP-OES), following the procedure outlined in [31].

ICP-OES Operating Conditions:
Instrument: ICP-OES (Agilent 5110; Germany)
RF Power: 0.7-1.5 kW (1.2-1.3 kW for axial view)
Plasma Gas Flow Rate (Ar): 10.5-15 L/min (radial), 15 L/min (axial)
Auxiliary Gas Flow Rate (Ar): 1.5 L/min
Viewing Height: 5-12 mm
Copy and Reading Time: 1-5 seconds (max 60 seconds)
Copy Time: 3 seconds (max 100 seconds)

3. Statistical analysis

We used the JMP program to analyse the data from statistical point of view and ANOVA for the the analysis of variance ($p<0.01$ and $p<0.05$). Fruit varieties (grapes, white cherries, red cherries, plums, pears, peaches, green apples, red apples, strawberries, lemons, limes, oranges, sour chery, blueberries) and vegetables (zucchini, eggplant, tomato, red pepper, green pepper, green bean, okra) dried with three different drying systems (shade, sun and oven). The correlation between nutrient contents was done using a multivariate cluster analysis Principal Component Analysis (PCA) performed byPAST statistical program [32].

4. Results and Discussion

4.1. Macro element amounts of dried fruits and vegetables

Macro element contents of some commercially important fruits (Grape, White cherry, red cherry, plum, pear, peach, green apple, red apple, strawberry, lemon, lime, orange, sour cherry and blueberry) dried in ovens, sun and shade are given in Table 1.

Significant differences were observed in the elemental contents of fruits depending on the type of drying. Among the oven and sun dried fruits, blueberry and plum contained the lowest amounts of K, while peach and lime fruits contained the highest amount of K, respectively. In addition, the lowest and highest K in sun-dried fruits were detected in pear and green apple fruits, receptively. In oven and sun dried fruits, green apple contained the lowest calcium, while orange and cherry fruits contained the highest calcium. In addition, red apple and orange fruits contained the lowest and highest Ca element among fruits dried in the shade, receptively. While pear and red apple dried in oven and sun contained the lowest amounts of P, the fruits containing the highest amount of P element in the same drying types were red apple and peach fruits, receptively. Phosphorus quantities of shade dried fruits were determined between 628.82 mg/kg (pear) and 2433.81 mg/kg (blueberry). S contents of fruits dried in oven and sun were determined between 162.74 (green apple) and 4888.75 mg/kg (blueberry) and 160.43 mg/kg (red apple) and 344.05 mg/kg (sour cherry). However, the S amounts of shade-dried fruits were determined between 109.67 mg/kg (red apple) and 546.43 mg/kg (blueberry). Also, while the Mg values of fruits dried in the oven were found to be between 225.10 mg/kg (red apple) and 1158.04 mg/kg (orange), the Mg contents of fruits dried in the sun were found to be between 239.04 mg/kg (red apple) and 928.28 mg/kg (orange). In addition, among shade-dried fruits, the lowest and highest Mg were detected in red apple (237.37 mg/kg) and orange (1362.97 mg/kg), respectively. The highest Ca contents in dried fruits were detected in lemon, lime, orange, sour cherry and blueberry. The amount of Ca in other fruits was found to be significantly lower. Among the fruits dried in the shade, the Ca amounts of white cherries, plums, pears, peaches, strawberries, lemons, limes and oranges were higher than those dried in the sun. This may possibly be due to the oxidation effect of sunlight on the element. It can be seen in Table 3 that dried fruits are rich in macroelements such as K, P and Mg. Depending on the drying types, the highest macro element contents in fruits were K, followed by P and Mg in decreasing order. The lowest K contents in dried fruits were determined in sun-dried fruits. P contents of fruits varied depending on drying types. However, there are numerical similarities between drying types with the highest P content in fruits. The lowest and highest Mg contents in fruits were determined in red apples and oranges, respectively, in all three drying types. In general, the highest Mg content was detected in oven-dried fruits, followed by shade- and sun-dried fruits in decreasing order.

Macro and micro element quantities of some vegetables (pumpkin, eggplant, tomato, red pepper, green pepper, green beans, okra) dried in ovens, sun and shade are given in Table 2. Element amounts of vegetables varied according to drying types. Depending on the drying types, element amounts of each vegetable showed statistical differences ($p<0.01$ and $p<0.05$). One of the elements found in the highest amounts in vegetables was Ca. While the Ca quantities of oven-dried vegetables vary between 959.90 mg/kg (red pepper) and 12361.10 mg/kg (green beans), the Ca quantities of sun-dried vegetables were determined between 729.53 mg/kg (eggplant) and 7561.13 mg/kg (okra). The lowest and highest Ca quantities of shade-dried vegetables were determined in eggplant (535.14 mg/kg) and okra (15243.80 mg/kg). One of the elements found in the highest amounts as a macroelement in dried vegetables was phosphorus. The P amounts of vegetables dried in the oven varied between 2536.26 mg/kg (green pepper) and 7382.44 mg/kg (pumpkin). The P contents of pumpkin dried in oven, sun and shade were significantly higher than those of other vegetables. The potassium, manesium and phosphor contents of pumpkin dried in oven, sun and shade environments were approximately 2-3 times higher than that of other vegetables. Potassium contents of eggplant, red pepper, green pepper and green bean were found to be close to each other. Statistically significant differences were detected between them depending on the drying conditions. After pumpkin, magnesium was determined most in okra.

Table 1. Macro element contents of the fruits dried by three different drying systems (mg/kg)

Fruits	P				K				Ca			
	Oven	**Sun**	**Shade**	**Mean**	**Oven**	**Sun**	**Shade**	**Mean**	**Oven**	**Sun**	**Shade**	**Mean**
Grape	1626.77 C-J	1586.08 D-J	1431.51 D-L	1548.12 BC	10396.99 C-F	8499.05 C-F	8445.28 C-F	9113.78 BCD	660.77 NOP	568.62 N-Q	417.44 P-S	548.94 GH
White chery	1293.60 E-N	1123.63 G-N	1569.39 D-J	1328.87 CD	10185.66 C-F	9656.24 C-F	10275.52 C-F	10039.14 BCD	1013.35 M	639.70 N-Q	853.12 MN	835.39 F
Red chery	1509.59 D-L	949.09 I-N	1681.45 B-J	1380.04 BCD	11927 31 CDE	6322.43 DEF	9411.19 C-F	9220.31 BCD	649.54 N-Q	532.91 O-R	317.42 P-S	517.95 H
Plum	1401.01 D-M	1375.94 D-M	1161.02 G-N	1312.65 CDE	9977.17 C-F	8519.67 C-F	10597.18 C-F	9698.01 BCD	842.68 MN	635.25 N-Q	807.36 MNO	761.76 F
Pear	751.44 LMN	1173.65 G-N	628.82 MN	851.30 E	5731.45 DEF	3412.83 EF	5221.63 DEF	4788.64 D	629.07 N-Q	438.24 P-S	470.56 O-R	512.62 I
Peach	1572.65	2487.60 A	2090.38 A-E	2050.21 A	13771.96 BCD	12724.20 B-E	13257.11 BCD	13251.09 AB	462.52 P-S	615.15 N-Q	1025.53 M	701.07 FG
Green apple	764.79 K-N	1572.77 D-J	738.62 LMN	1025.39 DE	9437.14 C-F	7720.54 C-F	22226.63 AB	13128.10 AB	194.91 S	244.96 RS	374.94 P-S	271.60 I
Red apple	1768.28 A-H	547.50 N	744.48 LMN	1020.09 DE	7276.98 C-F	6178.11 DEF	6554.85 DEF	6669.98 CD	447.18 P-S	357.72 QRS	196.10 S	333.67 I
Strawberry	1559.89 D-K	1476.67 D-L	2125.72 A-D	1720.76 ABC	9739.56 C-F	7907.28	12618.22 B-E	10088.36 A-D	2235.89 J	1490.31 L	1605.71 KL	1777.30 E
Lemon	2397.82 ABC	1123.62 G-N	1902.55 A-G	1807.99 AB	10879.72 CDE	6058.90 DEF	16650.12 BC	11196.25 ABC	5760.43 D	4143.24 G	7415.91 B	5773.20 B
Lime	1149.20 G-N	944.57 J-N	1060.42 N	1051.39 DE	10459.10 C-F	27610 A	9051.87 C-F	15706.99 A	2435.04 J	4430.54 FG	4550.10 F	3805.56 C
Orange	1558.41 D-K	1555.94 D-K	1984.08 A-F	1699.48 ABC	1040.05 F	9553.16 C-F	11349.73 CDE	7314.31 CD	6491.28 C	3616.96 H	8503.72 A	6203.97 A
Sour cherry	1245.06 F-N	1615.57 C-J	1394.03 D-M	1418.22 BCD	10965.39 CDE	9501.13 C-F	12489.70 CDE	10985.41 ABC	3194.31 I	5275.36 E	1366.52 L	3278.73 D
Blueberry	2015.78 A-F	1747.60 A-I	2433.81 AB	2065.73 A	1017.30 F	11127.12 CDE	9354.32 C-F	7166.25 CD	1899.40 K	2524.76 J	645.15 N-Q	1689.77 E
Mean	1472.45	1377.16	1496.16		8771.84 B	9627.90 AB	11250.24 A		1922.67 B	1688.15 C	2177.37 A	

A, B: $p<0.01$; a, b: $p<0.05$

Table 1 (continued; mg/kg)

Fruits	Mg				S			
	Oven	**Sun**	**Shade**	**Mean**	**Oven**	**Sun**	**Shade**	**Mean**
Grape	447.91 ST	344.07 U	349.01 U	380.33 I	430.86 D	313.89 E-H	258.85 IJK	334.53 C
White chery	527.11 QR	435.25 T	729.50 LM	563.95 GH	264.73 IJK	242.95 JK	338.45 E	282.04 DE
Red cherry	812.06 IJK	536.00 QR	674.42MNO	674.16 F	243.68 JK	251.12 IJK	315.70 EFG	270.17 DE
Plum	484.32 RST	580.70 PQ	647.73 OP	570.91 G	166.41 L	276.59 G-J	259.64 IJK	234.21 F
Pear	667.40 MNO	567.43	348.38 U	527.74 H	145.27 LM	172.60 L	114.94 M	144.27 H
Peach	574.96 Q	724.46 LMN	658.63NO	652.68 F	239.23 JK	165.16 L	224.41 K	209.60 G
Green apple	241.44 V	443.78 T	325.54 U	336.92 J	162.74 L	260.56 IJK	138.02 LM	187.11 G
Red apple	225.10 V	239.04V	237.37 V	233.84 K	163.24 L	160.43 L	109.67 M	144.45 H
Strawberry	970.83 CDE	826.60 HIJ	1336.95 A	1044.79 B	274.98 G-J	273.63 HIJ	327.70 EF	292.10 DE
Lemon	915.80 EFG	514.16 QRS	857.50 GHI	762.49 E	646.27 A	247.57 JK	445.39 D	446.41 AB
Lime	927.94 EF	743.81 KL	773.87 JKL	815.91 CD	323.19 EF	291,07F-I	262.66 IJK	292.31 DE
Orange	1158.04 B	928.28 EF	1362.97 A	1149.76 A	421.29 D	329,40 EF	526.81 BC	425.83 B
Sour cherry	1021.07 CD	560.01Q	968.62 DE	849.90 C	290.81 F-I	344,05 E	265.72 IJK	300.19 B
Blueberry	891.98 FGH	468.77 RST	1039.48C	800.08 DE	488.75 C	327,02 EF	546.43 B	454.07 A
Mean	704.71 B	565.17 C	736.43 A		304.39 A	261,15 B	295.31 A	

Table 2. Determining the changes in the macroelement contents of vegetables dried by three different drying systems (mg/kg)

Plants	Ca				K			
	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean
Pumpkin	2745.66 F	2746.22 F	2798.39 F	2763.43 C	45226.03	44137.94	48991.57	46118.51 A
Eggplant	2725.43 F	729.53 H	535.14 H	1330.03 D	24908.08	29308.60	25625.22	26613.96 B
Tomatoes	3527.91 E	1470.21 G	2565.61 F	2521.25 C	32262.74	25698.29	18565.34	25508.79 B
Red pepper	959.10 GH	880.15 GH	756.42 GH	865.22 E	27856.10	25697.02	25901.39	26484.84 B
Green pepper	1485.11 G	1074.93 GH	1057.44 GH	1205.83 DE	22523.25	15181.88	24062.75	20589.29 BC
Green bean	4414.03 D	4324.82 D	4238.21 D	4325.69 B	23438.35	26094.30	23156.24	24229.63 BC
Okra	12361.10 B	7561.13 C	15243.80 A	11722.01 A	18772.63	14745.88	18353.54	17290.68 C
Mean	4031.19 A	2681.36 B	3887.50 B		27855.31	25837.70	26379.43	

A, B: p<0.01; a, b: p<0.05

Table 2. (continued; mg/kg)

Plants	Mg				P			
	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean
Pumpkin	4751.46	4545.12	27747.32	11347.97 a	7382.44 C	9467.41 B	10494.68 A	9114.87 A
Eggplant	2044.09	1312.62	1705.67	1687.46 b	4140.95 HI	3767.74 I	4119.16 HI	4009.28 D
Tomatoes	1182.67	1336.75	1234.98	1251.47 b	5179.18 FG	3408.92 I	4606.53 GH	4398.22 D
Red pepper	1952.19	1657.93	1570.40	1726.84 b	4647.64 GH	3499.04 I	2406.69 J	3517.79 E
Green pepper	1711.67	1725.88	1472.17	1636.57 b	2536.26 J	3895.04 HI	3570.34 I	3333.88 E
Green bean	1711.67	1725.88	1472.17	1636.57 b	5069.18 FG	6187.55 DE	5438.22 EF	5564.98 C
Okra	2224.91	2638.39	2465.15	16363.57 b	6619.34 CD	6613.97 CD	6424.21 D	6552.51 B
Mean	6213.87	5680.75	5141.64		5082.15	5262.81	5294.26	

The magnesium contents of other vines did not change much depending on the drying media. While the lowest phosphorus was detected in green pepper, the P contents of other vegetables were higher than the K, Mg and Ca contents of the vegetables.

4.2. Micro element contents of dried fruit and vegetables

Micro element contents of some commercially important fruits (Grape, White cherry, red cherry, plum, pear, peach, green apple, red apple, strawberry, lemon, lime, orange, sour cherry and blueberry) dried in ovens, sun and shade are given in Table 3. While the lowest and highest Cu contents of oven-dried fruits were detected in lime (1.64 mg/kg) and grape (6.42 mg/kg), the Cu contents of sun-dried fruits were 1.52 mg/kg (lime) and 6.41 mg/kg (blueberry) was assessed between. The Cu content of fruits dried in the shade was determined between 1.86 mg/kg (green apple) and 5.56 mg/kg (grape). While red apple and strawberry fruits contain the lowest and highest iron amounts in sun-dried fruits, red apple and peach contained the lowest and highest iron amounts in shade-dried fruits, respectively. The lowest and highest Fe contents of fruits dried in the oven were determined in orange (10.58 mg/kg) and lemon (30.75 mg/kg), respectively. Additionally, oven-dried green apple and strawberry contained the lowest and highest amounts of Mn, while sun-dried lime and grape contained the lowest and highest amounts of Mn, respectively. Among the fruits dried in the shade, lime contained the lowest amounts of Mn, while blueberry contained the highest amounts of Mn. In addition, Mn amounts of shade-dried fruits were determined between 1.57 mg/kg (lime) and 23.86 mg/kg (blueberry). Depending on the fruit types, B contents of oven and sun dried fruits are 6.39 (pear) and 36.98 mg/kg (peach) to 5.98 mg/kg (red cherry) and 26.05 mg/kg (peach), respectively. In addition, B amounts of the fruits dried in shade changed between

Table 3. Micro element contents of the fruits dried by three different drying systems (mg/kg)

Fruits	Fe				Zn				Cu			
	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean
Grape	30.07 AB	12.30 K-N	11.64 LMN	18.00 EF	2.45 IJ	3.59 F-I	1.76 JK	2.60 EF	6.42 A	4.29 DEF	5.56 B	5.42 A
White chery	21.82 EFG	18.07 HI	10.25 NO	16.71 F	2.54 IJ	1.23 JK	1.71 JK	1.96 F	2.58 LM	1.54 O	2.61 LM	2.24 GH
Red chery	25.30 CD	27.58 BC	19.07 GHI	23.98 B	5.56 BCD	1.51 JK	2.55 IJ	3.21 E	5.51 B	2.39 LM	3.17 JK	3.69 CD
Plum	16.41 IJ	20.68 FGH	14.58 JK	17.22 EF	4.28 E-H	5.53 B-E	4.74 DEF	4.85 ABC	4.37 DE	3.36 IJ	3.72 GHI	3.81 C
Pear	18.36 HI	13.22 KLM	6.99 OQ	12.86 G	2.64 IJ	1.44 JK	1.88 JK	1.99 F	2.69 KLM	2.24 MN	3.80 F-I	2.91 E
Peach	20.79 FGH	23.92 DE	31.87 A	25.53 AB	3.31 HI	5.48 B-E	4.56 D-H	4.45 BCD	2.53 LM	1.63 O	3.55 IJ	2.57 F
Green apple	17.58 I	24.34 DE	13.85 JKL	18.59 DE	4.81 DEF	1.67 JK	1.85 JK	2.77 E	2.60 LM	2.56 LM	1.86 NO	2.34 FG
Red apple	18.17 HI	4.80 Q	5.74 PQ	9.57 H	0.89 K	0.98 K	0.85 K	0.91 G	1.86 NO	1.60 O	2.59 LM	2.02 HI
Strawberry	25.48 CD	32.15 A	22.05 EF	26.55 A	4.84 DEF	5.63 BCD	4.73 D-G	5.07 AB	4.89 C	2.78 KL	3.79 F-I	3.82 C
Lemon	30.75 A	30.60 A	12.45 K-N	24.60 B	7.57 A	1.78 JK	3.59 F-I	4.31 CD	4.65 CD	2.68 KLM	3.62 HIJ	3.65 CD
Lime	22.76 DEF	12.49 K-N	13.83 JKL	16.36 F	6.48 ABC	2.39 IJ	3.43 HI	4.10 D	1.64 O	1.52 O	2.49 LM	1.88 I
Orange	10.58 MNO	21.66 EFG	8.45 OP	13.56 G	2.55 IJ	3.46 GHI	3.43 HI	2.85 E	4.21 D-G	3.36 IJ	2.76 KLM	3.44 D
Sour cherry	20.86 FGH	25.11 CD	17.97 HI	21.32 C	5.26 CDE	3.46 GHI	4.73 D-G	4.48 BCD	4.09 E-H	3.60 HIJ	3.62 HIJ	3.77 C
Blueberry	18.38 HI	25.14 CD	16.58 IJ	20.04 CD	5.18 DE	4.47 D-H	6.54 AB	5.40 A	3.18 JK	6.41 A	4.53 CDE	4.71 B
Mean	21.24 A	20.86 A	14.67 B		4.17 A	3.01 B	3.31 B		3.66 A	2.86 C	3.40 B	

A, B: $p<0.01$; a, b: $p<0.05$

Table 3 (continued; mg/kg)

Fruits	Mn				B			
	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean
Grape	3.70 I	2.49 LMN	2.72 LM	2.97 EF	14.56 I-M	9.27 UVW	11.92 P-S	12.13 F
White chery	2.43 L-P	2.61 LM	3.53 IJ	2.85 F	9.36 UV	6.17 YZ	8.24 VWX	7.86 J
Red chery	4.61 H	2.32 M-Q	3.36 IJK	3.43 D	14.34 K-N	5.98 YZ	16.34 GH	12.15 F
Plum	2.50 LMN	4.35 H	2.84 KLM	3.23 DE	14.56 I-M	16.34 GH	29.66 B	20.19 C
Pear	4.33 H	3.47 IJ	1.89 N-R	3.23 DE	6.39 YZ	7.18 XYZ	5.90 Z	6.08 K
Peach	9.31 E	5.37 G	6.26 F	6.98 C	36.98 A	26.05 C	25.66 C	29.56 A
Green apple	1.44 R	1.81 POQ	2.76 KLM	2.00 HI	19.37 E	21.99 D	17.61 FG	19.66 C
Red apple	1.86 O-R	1.78 QR	1.64 R	1.76 I	31.23 B	19.11 EF	16.07 G-J	22.14 B
Strawberry	26.62 A	18.76 D	20.54 C	21.97 A	20.75 DE	9.64 TUV	10.37 STU	13.59 E
Lemon	3.53 IJ	1.78 QR	1.78 QR	2.36 GH	12.74 N-Q	7.09 XYZ	13.06 M-P	10.96 GH
Lime	2.44 LMNO	1.52 R	1.57 R	1.85 I	12.23 O-R	8.67 VWZ	7.61 WXY	9.50 I
Orange	2.80 KLM	3.47 IJ	2.59 LM	2.95 EF	11.26 Q-T	13.55 L-P	10.50 STU	11.77 FG
Sour cherry	3.01 JKL	2.56 LM	2.58 LM	2.72 FG	13.83 L-O	15.93 H-K	14.53 J-M	14.76 D
Blueberry	18.86 D	6.36 F	23.86 B	16.36 B	10.60 R-U	14.29 K-N	6.17 YZ	10.36 HI
Mean	6.25 A	4.19 C	5.57 B		16.365 A	12.93 C	13.73 B	

A, B: $p<0.01$; a, b: $p<0.05$

5.90 mg/kg (pear) and 25.66 mg/kg (peach). In addition, the Zn contents of fruits dried in the oven were recorded between 0.89 (red apple) and 6.48 mg/kg (lime), while the Zn contents of fruits dried in the sun were determined between 0.98 mg/kg (red apple) and 5.63 mg/kg (strawberry). In fruits dried in the shade, the lowest and highest Zn were detected in red apple (0.85 mg/kg) and blueberries (6.54 mg/kg). In general, the B contents of fruits dried in the sun were found to be slightly lower than those dried in the oven and in the shade. B contents of pear and white cherry fruits were found to be lower than those of other fruits. Among fruits dried in all three drying types, the highest B amounts were detected in peaches, red apples, strawberries, plums and cherries. In addition, significant changes were observed in the B contents of the fruits depending on the type of drying. The lowest Mn content was detected in limes dried in the sun and shade. In general, Mn contents of fruits were found to be at very low levels. In dried fruits, the highest Mn was detected in fruits saved in the oven, followed by fruits dried in the shade and sun in decreasing order. The lowest S contents were determined in red apples dried in the sun and shade, while the highest S contents were determined in blueberries dried in the oven and shade. Although S values in fruits showed statistical differences depending on the drying types, the values were found to be close to each other. In general, the Cu contents of grapes, sour cherries, plums, strawberries and blueberries were higher than those of other fruits. This may be due to the high concentration of plant nutrients and sufficient soil moisture in the soil where these plants grow. The Cu contents of the majority of fruits saved in the oven were found to be partially higher than those dried in the sun and shade. Among the fruits dried in all three drying types, red apple had the lowest Fe content. In general, the highest Fe contents detected in fruits were detected in sun-dried fruits, followed by oven-dried and shade-dried fruits in decreasing order. Among fruits dried in ovens, sun and shade, the lowest Zn was detected in red apples. In general, the Zn contents of plums, peaches, strawberries, cherries and blueberries, among the fruits dried in all three drying types, were higher than those of other fruits. Özcan et al. [33] determined 3046.37 ppm Ca, 13,531.96 K ppm, 1502.55 ppm Mg, 312.18 ppm Na, 1477.88 ppm P ain hawthorn fruits. Rodriguez *et al.* [34] pointed out that Ca contents of peaches changed between 5.1 and 9.12 mg/100g. Nour *et al.* [35] reported that the concentration of calcium in the apple samples ranged from 1.75 to 8.74 mg/100g. Olalla *et al.* [36] determined 0.052 mg/100g, 0.06 mg/100g, 0.06 mg/100g, 0.11mg/100g, 0.048 mg/100g, mg/100g 0.088 mg/100g Cu in melons, peaches, pears, strawberries and apricots respectively. Bennett *et al.* [37] studied dried fruit products and they found lower Ca, Mg, Na contents with the present study, but higher Mn content. Florentina-Cristina *et al.* [38] determined: 154 and 115 K, 3.7 and 6.25 mg/100 g Na, 1.05 and 1.45 Ca, 3.1 and 3.6 Mg, 0.095 and 0.1825 Fe, 0.28 and 0.255 Cu, 0.08 and 0.05mg/100g Zn in plum fruits (Chile) and Strawberry (Belgium), respectively. It was reported that sour cherry (Bucovat) and Cherry (Bulgaria) fruits contained: 156 and 134.5 K, 3.8 and 3.95 Na 5.7 and 3.15 Mg, 2.5 and 0.9 Ca, 0.13 and 0.065 Mn, 0.13 and 0.065 Fe mg/100g, 0.17 and 0.09 Cu, [38]. In rape fruit (Egypt) it was determined 4.95 mg/100g Na, 165.5 K, 0.85 Ca, 2.95 Mg, 0.275 Cu, 0.075 Mn, 0.0375 Fe and 0.02 mg/100g Zn [38]. Dağ et al. [39] determined 207-218mg/100g Ca, 132-141mg/100gMg, 20.47-21.82 mg/100g Na, 128.75-156.63 mg/100g Mn, 100.71-180.23 ppm, 54.56-64.50 ppm Cu, 52.66-63.21 ppm Zn Fe in sun drying, sulfured and sweet apticot samples. P, K, Ca, Mg and S were the macro elements of Hawthorn and Wild Pear Fruits [40]. Mohammed *et al.* [41] determined 8.48-13.22 g/100g Ca, 6.01-7.99 g/100g P, 0.015-0.083 g/100g Fe, 0.008-0.032 g/100g Mn, 0.110-0.162 g/100g Zn, 0.022-0.039 g/100g Cu in fresh and dried Mangoes fruits.

In a previous study, the operating conditions of convective infrared drying were shown to significantly influence fluctuations in nutrient elements in fruits like strawberries [25]. The concentrations of chemical elements such as N, P, K, and Mn was increased by higher drying temperature of air, while the contents of Zn and Ca were reduced. It was shown that by applying the various infrared power, the concentrations of N, P, and K increased, while the contents of Ca, Mg, Fe, Mn and Zn were lowered. Also, the concentrations of N, P and K increased and contents of Ca, Mg, Fe and Zn decreased at different drying air velocities, highlighting the importance of optimizing the drying process to ensure the best chemical compositions of a dried product. Each drying technique depends on various factors, such as the required type of product, size, level of ripeness, structure, color, aroma, chemical composition, nutritional composition, together with expected final quality, availability of a dryer and costs [2]. Depending on the type of drying, some differences were detected when the biogenic element contents of fruits were compared with the element contents of fruits in recent studies. In addition, significant differences were detected in the macro and micro biogenic element contents of the fruits depending on the drying types.

These differences may have varied depending on the nutrient content of the soil where the fruits were grown, irrigation water, harvest time, locations, type of drying applied and temperature, and light intensity, as well as fruit types.

As for microelements, Boron quantities of oven and sun dried vegetables were recorded to be between 21.67 mg/kg (green beans) and 29.52 mg/kg (eggplant) to 9.22 mg/kg (red pepper) and 35.50 mg/kg (tomato), respectively (Table 4). Boron contents of pumpkin, eggplant and okra vegetables dried in oven, sun and shade were found to be higher than those of other vegetables. Among the microelement quantities of dried vegetables, Fe was found in the highest amounts. Fe quantities of oven-dried vegetables were recorded to be between 27.50 mg/kg (tomato) and 94.98 mg/kg (pumpkin). Fe amounts of shade-dried vegetables were determined to be between 9.69 mg/kg (tomato) and 85.41 mg/kg (pumpkin). The element found in the highest amounts in vegetables was potassium. Mn, one of the micronutrients of vegetables dried in ovens, sun and shade, was found at low levels. But, In general, the highest Mn was assessed in vegetables dried in the oven, shade and sun, in decreasing order. Another microelement detected in dried vegetables was Zn. Zinc quantities of oven and sun dried vegetables were recorded between 10.20 mg/kg (green pepper) and 46.84 mg/kg (okra) to 9.44 mg/kg (green pepper) and 45.42 mg/kg (okra), respectively.

It has been stated that vegetables contain high amounts of Ca, K, P, Cl and S, and although these elements are considered essential elements for the human body, they may pose a health risk with long-term consumption. It has been reported that the high amounts of macro elements in vegetables may be due to the high content of these metals in the soil [42]. The deficiency of potassium in the diet, which is one of the basic elements of the human diet and plays an important role in vital cellular mechanisms, may cause resistance to insulin in fat and muscle cells, increase in serum triglycerides, and decrease in serum triglycerides [43]. Absorption of the surrounding air by the leaf may cause the Fe content of leafy vegetables to increase. Codex Alimentarius Commission stated that the amount of Fe in foods is between 2.5-5.0 mg/kg and the daily amount of Fe that can be taken varies between 10 and 50 mg/day [44]. For this reason, the Fe amounts determined in our study, depending on the drying type, are well above the recommended Fe amounts according to [45] and [44]. Zinc provides the catalytic activity of more than 200 enzymes involved in various aspects of cellular metabolism [46]. Copper, which has an important role in human metabolism, largely allows many critical enzymes to function properly, as well as acting as an antioxidant, scavenging free radicals and may reduce or help prevent some of the damage they cause [47]. All leafy vegetable samples contain varying amounts of elements, which can be attributed to factors such as variation in the genetic structure of plant species and the competitive interaction between metal ions within the lithosphere or variation in mineral amounts in the soil in which the vegetables grow [48].

As a result, the lowest Ca content was measured in eggplant dried in the sun and shade. Ca amounts were detected in sun-dried vegetables. The lowest and highest K contents of vegetables dried in all three drying types were measured in okra and pumpkin, respectively. The lowest and highest Mg contents of vegetables dried in oven, sun and shade were observed in red pepper (except sun drying) and okra, respectively. The highest P content was detected in pumpkin. However, the P contents of squash dried in the sun and shade were higher than those dried in the oven. The lowest B content was detected in red pepper in all drying types. In general, B contents of shade-dried vegetables were found to be slightly lower than oven-dried and sun-dried vegetables. As with the B content of vegetables, in general, the lowest Cu contents of vegetables were recorded to be low depending on the drying types. In general, the lowest Cu contents were detected in sun-dried vegetables. Cu contents of zucchini, green beans and okra were found to be partially higher than those of other vegetables in all three drying types. Fe contents of vegetables varied depending on the type of drying. Fe contents of tomatoes dried in the oven and sun increased significantly (about 3 times more) than those dried in the shade. The increase in the same drying types was also observed in eggplant, but the increase rate was relatively low. In addition, the lowest and highest Mn contents of vegetables dried in all three drying types were determined in red pepper and okra, respectively. Additionally, it has been observed that, in general, vegetables dried in the oven contain more Mn than vegetables dried in the sun and shade. This may be due to the fact that the dry matter rate is higher than when dried in the sun or shade, possibly due to the heat treatments applied. The vegetables with the lowest and highest S content dried in the oven and in the shade were tomatoes and okra, respectively. The lowest and highest Zn contents of vegetables dried in all three drying types were determined in green pepper and okra, respectively. In general, the Zn contents of vegetables dried in the oven were found to be higher than those of vegetables dried in the sun and shade. The levels of some mineral element contents of broccoli, cauliflower, curly kale, red cabbage, and lentils sold in Yankaba Market of Kano

Table 4. The micro element contents of vegetables dried by three different drying systems (mg/kg)

Plants	B				Cu				Fe			
	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean
Pumpkin	24.66 CD	27.78 BC	26.93 BC	26.46 B	9.88 CD	16.20 A	16.07 A	14.05 B	74.22 C	94.98 A	85.41 B	84.87
Eggplant	29.52 B	13.56 EFG	12.73 FGH	18.61 D	6.78 F	7.39 F	5.26 HI	6.48 D	43.49 FG	44.78 EF	27.61 JK	38.63
Tomatoes	39.16 A	35.50 A	26.48 BC	33.71 A	7.36 F	6.54 FG	4.76 I	6.22 D	32.56 IJ	27.50 JK	9.69 L	23.25
Red pepper	13.70 EFG	9.22 HI	7.05 I	9.99 E	4.55 IJ	3.77 J	5.39 HI	4.57 E	47.20 EF	33.76 HI	26.65 K	35.87
Green pepper	14.51 EF	9.43 HI	10.06 GHI	11.33 E	4.55 IJ	2.83 K	5.72 GH	4.37 E	38.66 GH	47.31 EF	37.88 GHI	41.28
Green bean	21.67 D	13.47 EFG	16.49 E	17.21 D	9.52 D	8.58 E	10.76 C	9.62 C	78.01 C	60.73 D	74.66 C	71.13
Okra	25.55 C	15.77 EF	25.09 C	22.38 C	16.44 A	12.79 B	16.21 A	15.15 A	49.78E	35.76 HI	37.28 HI	40.94
Mean	24.11 A	17.82 B	17.94 B		8.44 B	8.30 B	9.17 A		51.99 A	49.26 B	42.74 C	

A, B: p<0.01; a, b: p<0.05

Table 4 (continued)

Plants	Mn				Zn			
	Oven	Sun	Shade	Mean	Oven	Sun	Shade	Mean
Pumpkin	14.48 C-G	18.67 BCD	20.91 B	18.02 B	24.02	40.55	31.77	32.12 ab
Eggplant	17.08 B-E	9.16 H-K	12.50 E-I	12.91 C	11.90	10.94	11.51	11.45 b
Tomatoes	19.06 BC	7.94 IJK	9.72 G-K	12.24 C	11.81	11.08	6.64	9.84 B
Red pepper	11.44 F-J	6.83 JK	5.30 K	7.86 D	15.89	9.49	7.69	11.02 b
Green pepper	14.12 D-G	13.10 E-H	15.14 C-F	14.12 C	10.20	9.44	7.60	9.08 b
YeşGreen bean	15.79 C-F	14.79 C-F	13.54 E-H	14.71 C	12.41	28.15	16.90	52.49 a
Okra	32.27 A	31.66 A	34.63 A	33.85 A	46.84	45.42	45.87	46.04 a
Mean	18.17 A	15.96 B	14.59 B		19.01	18.55	36.18	

A, B: p<0.01; a, b: p<0.05

State, Nigeria had 43.09 to 76.67 mg/kg Ca, 0.04 to 2.33 mg/kg Co, 0.89 to 7.20 mg/kg Cu, 0.71 to 9.88 mg/kg Fe, 12.83 to 69.09 mg/kg K, 15.63 to 86.63 mg/kg Mg, 0.51 to 1.77 mg/kg Mn, 8.65 to 37.36 mg/kg Na, and 0.7-11.88 mg/kg Zn, respectively [49]. Results showed some changed compared to results of last studies carried out on leafy and green vegetables. These changes can be likely due to variety, soil and environment factors, plant parts, wild and cultivated plants and some analytical conditions. Also, fluctuations in element contents of analyzed plants can be attributed to differences in element uptake and translocation abilities of the plant, plant species and growth stages, soil properties and geo-environmental conditions [50]. As a results, B and Cu contents of red pepper were much lower than other vegetables. B and Fe contents of sevze dried in oven were partially higher than those dried in sun and shade. This may be caused by contact of the dried material with metals. The lowest B was detected in green pepper dried in the shade. No statistical difference was observed between the B contents of oven-dried red pepper and green pepper. In general, B, Cu and Fe contents of shade-dried vegetables were found to be lower than those of other drying types. The lowest Zn content was detected in red pepper and green pepper vegetables dried in the sun and shade.

4.3. *Principal Component Analysis for fruits and vegetables*

Various fruit varieties (including grapes, white cherries, red cherries, plums, pears, peaches, green apples, red apples, strawberries, lemons, limes, oranges, cherries, and blueberries) were dried using three different methods: shade drying, sun drying, and oven drying. The Pearson correlation (r) between macro (P, K, Ca, Mg, and S) and micro (Fe, Zn, Cu, Mn, and B) nutrient contents is shown in Figure 1.

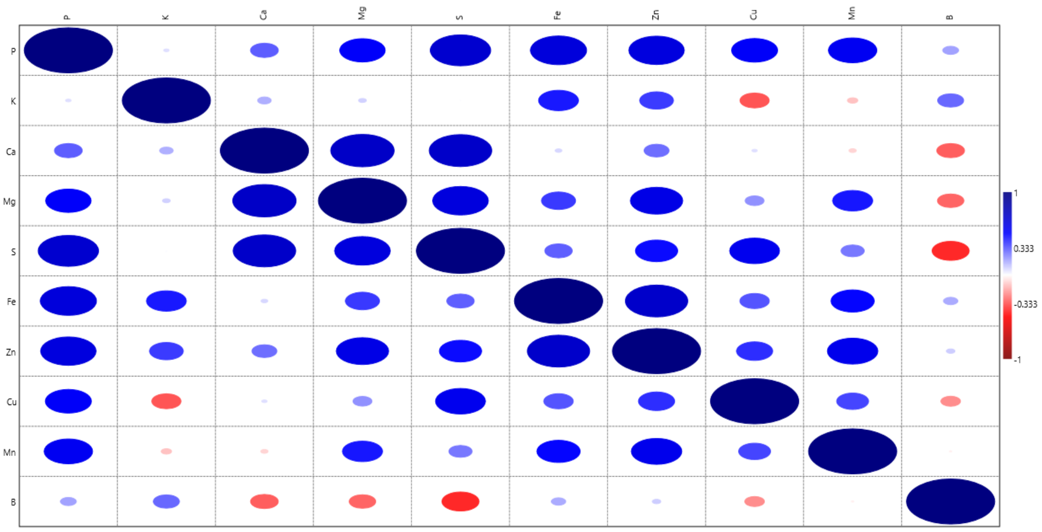

Figure 1. Fruit varieties (grapes, white cherries, red cherries, plums, pears, peaches, green apples, red apples, strawberries, lemons, limes, oranges, cherries, blueberries) dried with three different drying systems (shade, sun and oven). Pearson correlation (r) between macro (P, K, Ca, Mg and S) and micro (Fe, Zn, Cu, Mn and B) nutrient contents.

Positive correlations were found between phosphorus (P) content in fruits dried by different methods and other nutrient elements, with sulfur (S) (r = 0.685**), iron (Fe) (r = 0.637**), zinc (Zn) (r = 0.629**), and manganese (Mn) (r = 0.5223**) showing significant, moderately strong relationships ($p < 0.05$, r = 0.30-0.70).

Additionally, strong positive correlations ($p < 0.05$, r = 0.30-0.70) were identified between calcium (Ca) content and both magnesium (Mg) (r = 0.719**) and sulfur (S) (r = 0.709**) in the fruit varieties. As seen in Figure 1, significant, moderately strong positive correlations were also observed between Mg content and both S (r = 0.632**) and Zn (r = 0.594**). Similarly, a positive correlation was found between S content and copper (Cu) (r = 0.566**).

When analyzing iron (Fe) and zinc (Zn) levels in fruits dried by different methods, a highly significant positive correlation was found between Fe and Zn content (r = 0.707**), along with a significant, strong positive relationship between Zn and Mn content (r = 0.573**).

Overall, Pearson correlation revealed moderately strong positive relationships across these nutrient elements. Macro (P, K, Ca, Mg and S) and micro (Fe, Zn) types of vegetables (zucchini, eggplant, tomato, red pepper, green pepper, green bean, okra) dried by applying different drying techniques (shade, sun and oven). Pearson correlation (r) between nutrient contents (Cu, Mn and B) is given in Figure 2.

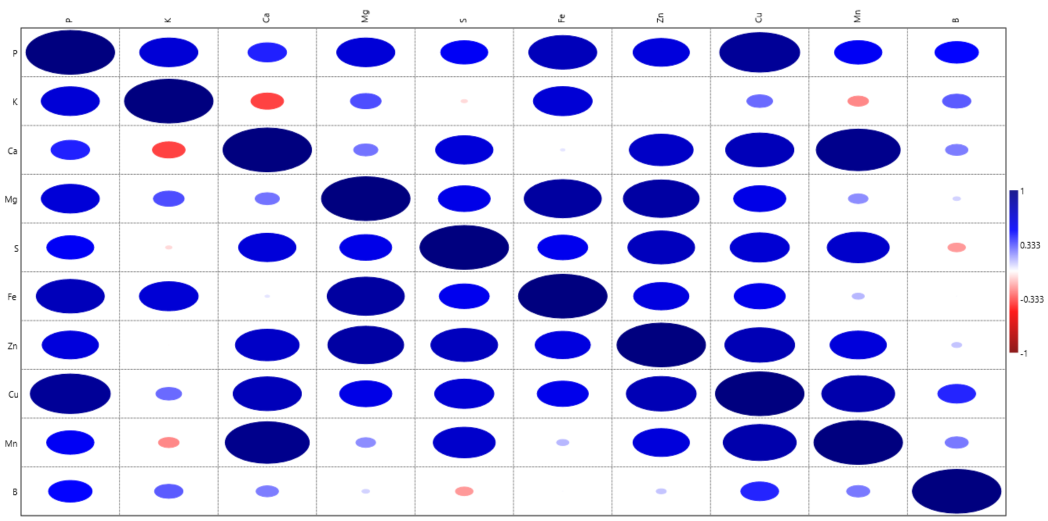

Figure 2. Macro (P, K, Ca, Mg and S) and micro (Fe, Zn) types of vegetables (zucchini, eggplant, tomato, red pepper, green pepper, green bean, okra) dried by applying different drying techniques (shade, sun and oven). Pearson correlation (r) between nutrient contents (Cu, Mn and B).

It was determined by Pearson correlation that there were positive relationships between the nutritional elements of vegetable varieties dried with different drying techniques. While it was determined that there were significant and moderately strong positive relationships ($p<0.05$, r= 0.30-0.70, r=0.636**) between the P contents and Cu contents of vegetable varieties, there were also significant and high-strong positive relationships with their Fe contents ($p<0.05$, r>). 0.70, r = 0.768**). As can be seen from examining Figure 2, significant and highly positive relationships were found between the Ca contents and Cu contents (r=0.771**) and Mn contents (r=0.948**) of dried vegetable varieties. It has been revealed that there are significant and strong positive relationships between the Mg contents and Fe (r=0.871**) and Zn contents (r=0.856**) of vegetables dried with different technique. In addition, this study determined that there were significant and highly strong positive relationships between the Zn and Cu contents of vegetable varieties and the Cu (r=0.788**) and Mn (r=0.824**) contents, respectively.

5. Conclusion

Significant differences were observed in the elemental contents of fruits depending on the type of drying. Dried fruits are rich in macroelements such as K, P and Mg. Depending on the drying types, the highest macro element contents in fruits were K, followed by P and Mg in decreasing order. The lowest K contents in dried fruits were determined in sun-dried fruits. The highest Ca contents in dried fruits were detected in lemon, lime, orange, sour cherry and blueberry. The lowest Ca amounts were detected in sun-dried vegetables. The lowest Ca content was measured in eggplant dried in the sun and shade.The Cu contents of the majority of fruits saved in the oven were found to be partially higher than those dried in the sun and shade. Among the fruits dried in all three drying types, red apple had the lowest Fe content. Among fruits dried in all three drying types, the highest B amounts were detected in peaches, red apples, strawberries, plums and cherries. Cu contents of vegetables were recorded to be low depending on the drying types. In general, the lowest Cu contents were detected in sun-dried vegetables. Cu contents of zucchini, green beans and okra were found to be partially higher than those of other vegetables in all three drying types. Fe contents of vegetables varied depending on the type of drying. Fe contents of tomatoes dried in the oven and sun increased significantly (about 3 times more) than those dried in the shade. Tt has been observed that, in general, vegetables dried in the oven contain more Mn than vegetables dried in the sun and shade.

Conflicts of interest/Competing interests: No conflict of interest

Ethics approval: No ethic situation.

Availability of data and material: The data have been reviewed depending on the literature.

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