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The Effect of Different Processing Methods on the Behavior of Minerals Content in Food Products

Khalid S. Alshallash[1], Mohamed Shahat[2], Mohamed I. Ibrahim[2], Ahmed I. Hegazy[2], Ashraf E. Hamdy[3*], Ibrahim A. Elnaggar[3], Abd El-Wahed N. Abd El-Wahed[3], Ibrahim M. Taha[2*]

[1] College of Science and Humanities-Huraymila, Imam Mohammed Bin Saud Islamic University (IM SIU), P.O. Box. 5701, Riyadh 11432, Saudi Arabia

[2] Department of Food Science and Technology, Faculty of Agriculture, Al-Azhar University, Cairo 11884, Egypt

[3] Department of Horticulture, Faculty of Agriculture, Al-Azhar University, Cairo 11884, Egypt

* Corresponding author's e-mail: ashrafezat@azhar.edu.eg; ibrahimtaha164@azhar.edu.eg

ABSTRACT

The goal of the current study was to determine the mineral content of different fruit varieties (Na, K, Ca, P, Mg, Fe, Zn, and Cu), as well as the effects of various processing methods (such as canning, drying, stewing, syrup process, and concentration of juices). All tested fruits that were subjected to various types of processing were exposed to a degree of mineral loss, varying from very little to high reduction. However, it still retains its nutritional value. All fig products have the greatest levels of most tested minerals, compared to other processed fruit products, particularly P and Fe. In turn, orange products supply higher quantities of Ca. On the other hand, apricot products have a comparable value of other minerals with those found in fig and orange products. Among canned juices, guava had the highest contents of Ca, P, and Fe, while mango scored the first juice as Mg and Zn supplying. Canned apricot halves contain the best amounts of K, Ca, P and Mg than the same products of apple and peach. Among jam products, fig jam has higher amounts of Na, Ca, P, Mg, and Fe than those found in other fruit jams. The concentration of fruit juices by vacuum-heating or dehydration of fruit produced higher mineral retentions than the fruit products that were processed by other techniques. The concentrated orange juice by vacuum-heating processing retained most of the minerals found in raw juice, also dried apricot sheet retained higher minerals than those retained in dehydrated whole apricot.

Keywords: minerals, fruit, processing, canning, dehydration, stewing.

INTRODUCTION

To benefit from the health and nutritional advantages of fruit and vegetables, it is advised by the World Health Organization (WHO) that a minimum daily intake of 400 g be followed. Fresh fruit intake rises as a result of this suggestion. Around 3.9 million deaths worldwide in 2017 were attributed to consuming too few fruits and vegetables (Khairunnisa et al., 2022). According to estimates, eating too little fruit and vegetables contributes to 14% of global deaths from gastrointestinal cancer, 11% of deaths from ischemic heart disease, and 9% of deaths from stroke (Afshin et al., 2019). The severity of several infectious diseases may be lowered by eating enough fruit and vegetables. Consuming fruit and vegetables does not provide protection against viruses like COVID-19, but they will help recovering from an infection more quickly than in the case of diets low in this food group (Chowdhury et al., 2020).

Fruit and vegetable-rich diets are highly recommended for their ability to promote health. Because of the vitamins and minerals they provide, fruits and vegetables have historically been included in dietary recommendations (Yahia et al., 2019). Minerals can be found naturally in fruits.

Natural inorganic chemicals called minerals are crucial for the body's normal operation (Bonewit-West and Hunt, 2019). The current state of knowledge suggests that certain microelements are essential for the proper growth and operation of the human body. Minerals are needed by people to fulfill their physiological needs (Alajil et al., 2021). For example, calcium and phosphorus are important for the development and homeostasis of bones, teeth, and muscles. The heart muscle, blood coagulation, and neuromuscular transmission all depend on calcium, which is a vital component of human blood and extracellular fluid (Brzezińska-Rojek et al., 2022). Additionally, calcium is necessary for the skeletal system, and a lack thereof causes osteoporosis, a public health issue that is particularly prevalent in developing nations (Rojas-Molina et al., 2015). Magnesium keeps the electrical potential in the neurons and activates a variety of enzyme systems. It supports the osmotic balance in plasma and extracellular fluid, where it is crucial (Brzezińska-Rojek et al., 2022). Mg is an essential component of bones and teeth. It functions as a cofactor for numerous human enzymes, including ATP-dependent kinase, and it has an impact on membrane permeability as well as neuromuscular transmission (Long and Romani, 2014). Potassium is an electrolyte that helps to maintain a healthy fluid balance, controls heartbeat, keeps blood pressure at a normal level, and reduces the risk of stroke (Fratianni et al., 2018). Due to the struggle between these two ions in the human diet, Na is associated with K; as a result, the people suffering from hypertension are advised to consume more water (Stone et al., 2016). Because of its connection to the condition of hypertension, a restricted intake of Na is advised (Du et al., 2014).

As a core ion, iron is a vital component of hemoglobin. One of the three most common types of mineral deficiency globally is due to inadequate consumption of Fe (Miller et al., 2013). Iron not only makes up several enzymes but also the haem that forms the hemoglobin's prosthetic groups (Székely et al., 2019). Additionally, it contributes to the creation of DNA and is essential for the proper operation of the immune system (Briguglio et al., 2020). Both copper and zinc are elements of numerous enzyme systems and are involved in the development of the immune response (Chasapis et al., 2020; Chen et al., 2020). Skin inflammations, atherosclerotic processes, infections, and problems with the skeletal and reproductive systems can all result from low amounts of zinc in the body (Gergely et al., 2014; Prasad, 2014). Zinc plays a role in the control of the cardiovascular system and the process of mending wounds (Chasapis et al., 2020). A Zn shortage together with an excess of Cu is also seen in autistic children (Bjørklund, 2013). According to the European Food Safety Authority (EFSA), an appropriate intake (AI) for Zn for an adult man is around 10 mg per day, whereas the AI for copper is 1.6 mg per day ((EFSA), 2017). Because it is a part of metalloenzymes, copper is a crucial component of mammalian nutrition (Stern et al., 2007). Additionally, Cu is necessary for the efficient functioning of the skeletal system, connective tissue, and blood vessels, as well as for the absorption of Fe (Chen et al., 2020).

Fruit products come in a wide range of processing levels, from the least processed (fresh and dried fruits) to the most processed (fruit juice with added sugars, fruit-based sodas, ultra-processed products with fruit preparations like filled or coated biscuits, dairy desserts, ice cream, etc.), with intermediate transformations (100% fruit juice, canned fruit, compote, jams, etc.) (Fardet et al., 2019). There are three categories of fruit-based products: unprocessed (raw, dried, pressed, and/or cooked fruits without added sugars), processed (fruits with added sugars, such as canned fruits with syrup, nectars, fruit cocktails, jams, and marmalades, and fruit juices with added sugars), and fruit-based desserts.

These fruit products may be mostly regarded as minimally processed under the NOVA classification given the applied procedures, which include washing, sorting, sizing, trimming (pitting, tailing, and peeling), cutting, blanching (1-2 minutes in boiling water), preserving, drying, and packaging (Monteiro et al., 2016). On the other hand, since most fruits are seasonal and have a short shelf life, they must be treated to make them safe, more stable, and more appealing. Therefore, it is crucial to comprehend how processing affects the different food ingredients.

The impact of processing on the nutrients of vegetable and fruit products has been covered in several review publications (Ojwang et al., 2021; Orlando et al., 2022; Teribia et al., 2021; Yeasmin et al., 2021). Naturally, there is a lot of interest in how processing affects the concentration of vitamins and phytochemicals, but less research has been done on how processing affects the mineral content of fruit.

Many workers looked at the mineral loss in various foods during canning and dehydration techniques (Ekholm et al., 2007; Hussain et al., 2010). They discovered that several variables, including the type of material used, the packing material, and the period of storage, affected how much leaching occurred. When veggies were canned, about 20% of Ca, 50% of K, 32% of Zn, 90% of Na, 70% of Fe, 40% of P, and 50% of Mg were removed (Amagloh et al., 2012; Morgounov et al., 2007; Wu et al., 2008). However, according to another study, the majority of foods only suffered minor mineral losses while canning (Hussain et al., 2010; Rickman et al., 2007), and the majority of minerals are less likely to leach when being processed. The retention rate of each element in treated fruits was surface-dependent: weight ratios of fruit products and fruit types that are affected by genetic diversity, rate of maturity, post-harvest handling, and pre-treatments during growing, such as soil quality, fertilizer use and type, climatic, water, and light availability (White et al., 2009; Wu et al., 2008). In general, fresh fruits and their processed products supply minerals for the human diet; but, depending on how they were processed beforehand, their mineral content may change. Therefore, a basic study is necessary to forecast variations in mineral retention in fruit products after different processing.

Table 1. Raw fruits used in this study

No	Common name	Scientific name
1	Anna apple	*Pyrus malus*
2	Balady orange	*Citrus Sinensis*
3	Balady grapefruit	*Citrus paradise*
4	Amar apricot	*Prunus armeniaca*
5	Sinai peach	*Prunus persica*
6	Balady mango	*Mangifera indica*
7	Barshomi Sultani fig	*Ficus carica*
8	Banati grape	*Vitus vinifera*
9	Balady guava	*Psidium guava*

The goal of this study was to assess the mineral composition of a variety of locally popular fruits, as well as the product's nutritive value as a source of minerals, and to forecast the mineral changes that may occur due to various processing techniques typically employed for each fruit type. Comparisons were also made to the number of necessary adult persons, according to the Food and Agriculture Organization of the United Nations reference; then, the extent to which these fruits can supply humans with vital minerals was determined.

MATERIALS AND METHODS

Materials

Before the macro- and micro-minerals were determined, nine local fruit varieties (Table 1) were processed using various techniques. Fruit samples from commercial markets were selected in 2022 for the season and at a maturity level suitable for processing methods. The analytical grade chemicals and solvents were obtained from El-Gamhouria Trading Chemicals and Drugs Company, Cairo, Egypt.

Methods

Processing procedures

The preparation and processing operations applied for each type of tested fruit are shown in Table 2. On a lab scale, processing procedures were carried out under (as far as possible) the same conditions as those used in commercial production. The samples of fresh fruit were cleaned before undergoing pre-treatment procedures like peeling, pitting, cutting, and pressing of pulps to

Table 2. Preparing and processing operations applied in this study

Operation			Processed fruits
Pre-treatments	Peeling		Apple, orange, and grapefruit
	Juice extraction		Orange and grapefruit
Processing methods	Canning	Juices	All fruits, except peach, grape, and fig
		Fruits	Apple (slices), peach, and apricot (halves)
	Dehydration	Whole fruit	Apricot, fig, and grape
		Fruit sheet	Apricot
	Concentration	Freeze	Orange juice
		Vacuum-heat	Orange juice
	Pasteurized	Syrup	Apricot and mango
	Stewing	Jam	Apricot, peach, and fig

extract the juice. Depending on the processing techniques applied for each fruit species, blanching (or lye dipping) and sulfuring were performed. Processing techniques include stewing and canning (Rickman et al., 2007), syrup (Adewusi et al., 1999), dehydration (Shahat et al., 2016), and juice concentration techniques (Davis, 2009) were carried out for the fruits under this investigation.

Minerals determination

According to the explanation provided by the ashing process, the macro-minerals (sodium, potassium, calcium, phosphorus, and magnesium) and micro-minerals (iron, zinc, and copper) were taken from the fresh raw, pre-treated, and processed fruits (Jan et al., 2022). To identify the mineral components, the sample was dissolved in 50 ml of the di-acid mixture (HNO_3:$HClO_4$, 5:1, v/v). Atomic absorption spectroscopy was used to determine the amounts of Mg, Fe, Zn, and Cu (AAS, AA4000, Spectrum-SP, Darmstadt, Germany). Na, Ca, and K were measured using a flame photometer (128, Systronics, Ahmedabad, India). A UV-VIS spectrophotometer was used to measure P using the method of (Bouhlali et al., 2020). On a dry weight basis, the concentrations of Na, K, P, Ca, and Mg was measured as mg/100g samples. On a dry weight basis, the amounts of Fe, Zn, and Cu were measured as mg/kg samples.

RESULTS AND DISCUSSION

Content of mineral elements in the tested raw fruits

According to the FAO/WHO dietary recommendations, Table (3) compares the mineral concentrations of various fresh fruit samples. The examined fresh fruits were found to contain Na, K, Ca, P, and Mg at amounts ranging from 1 to 287 mg/100g sample on a dry weight basis, according to the results. On a dry weight basis, the amounts of Fe, Zn, and Cu in the same samples ranged from 0.3 to 9 mg/kg. In comparison to the other studied fruits, guava fruit had higher concentrations of K (287 mg/100g), P (42 mg/100g), and Fe (9 mg/kg). Mango fruit had the highest concentrations of Na, Mg, and Zn (7.1, 20.4 mg/100g, and 2.2 mg/kg, respectively), whereas orange fruit had the highest concentrations of Ca.

The effect of pre-processing treatments on mineral elements in fruits

Fresh fruits are subjected to various procedures before they are subjected to the selection process, such as peeling, pulp juicing, etc., to make them suitable for the process. All minerals were reduced and observed in Zn, Fe, Cu, and Ca (40, 34, 21, and 18%, respectively) when the apple was peeled, as indicated in Table 4 and Figure 1. The idea that some of these minerals are embedded in layers right beneath peels may be related to this. Rahman et al. (2015) discovered that several minerals, including phosphorus, potassium, calcium, magnesium, iron, and zinc, were lost during the peeling of potatoes. This might be because unpeeled potatoes contain more solutes than peeled ones do.

Additionally, although weight loss from trimming may be minimal, significant nutrient losses may occur since several vitamins and trace minerals are frequently concentrated in the outer layers of vegetables, roots, seeds, and fruits (Amagloh et al., 2012). However, the K, P, and Mg

Table 3. Minerals content of tested raw fruits compared to dietary recommendations of FAO/WHO

Minerals	Raw fruit									Dietary Recommendations (mg/day)
	Apple	Orange	Grapefruit	Mango	Grape	Peach	Fig	Apricot	Guava	
Mg /100g										
Na	1.1	1.0	1.4	7.1	1.5	1.5	23	1.0	4.0	1500
K	115	200	234	189	173	225	133	281	287	3500
Ca	7.4	61.2	16.0	16.2	12.4	7.6	18.0	17.2	23.3	1000
P	11.3	20.2	16.0	18.6	20.0	20.1	11.6	21.3	42.0	700
Mg	5.4	11.3	10.4	20.4	6.4	6.9	9.8	12.2	13.1	420
Mg /kg										
Fe	5.0	2.7	4.0	5.0	4.1	5.0	6.0	3.7	9.0	10
Zn	0.5	1.0	0.3	2.2	0.4	2.0	1.0	0.6	0.8	11
Cu	1.4	0.6	0.6	1.2	1.0	5.0	1.0	1.2	0.4	0.9

Table 4. Minerals content of a raw apple, orange, and their processed products as affected by pre-processing and processing procedures

Minerals	Apple					Orange						
	Raw fresh	*Peeled pulp	Stewed (jam)	Canned		**Raw pulp	Fresh juice	Canned juice	Concentrated juice			
									Freezing		Vac. Heating	
				Slices	Juice				Conc.	Re-conc.	Conc.	Re-conc.
Mg /100g												
Na	1.1	1.0	1.6	1.8	1.6	1.0	1.8	1.3	2.7	0.7	3.1	1.6
K	115.0	110.0	51.0	41.0	78.0	200	319	272	160	90	413	310
Ca	7.4	6.1	3.2	4.9	4.3	61.2	36.7	30.4	73.4	31.5	90	35.3
P	11.3	10.5	5.2	6.4	8.0	20.2	27.0	22.5	55.1	12	80.7	27
Mg	5.4	5.0	2.7	2.4	3.7	9.1	11.3	9.6	16.7	6.3	27.6	11
Mg /kg												
Fe	5.0	3.3	1.7	3.0	2.5	4.5	2.7	2.2	9.0	2.3	11.4	2.8
Zn	0.5	0.3	0.2	0.2	0.2	0.9	1.0	0.8	1.0	0.4	1.8	0.8
Cu	1.4	1.1	0.5	0.6	0.9	0.5	0.6	0.5	0.8	0.3	1.0	0.6

concentrations of an identical sample were marginally decreased (from 4 to 7%).

When the juice from orange and grapefruit pulps was extracted, 40% of the calcium or iron was retained in the orange pulp and 45% of the calcium or iron was retained in the grapefruit pulp, while the majority of the other tested minerals mostly passed into the juices, as shown in Tables 4, 5 and Figures 2, 3. This may be connected to the fact that other minerals may be present in a soluble condition, while Ca and Fe may be bound with insoluble substances (such

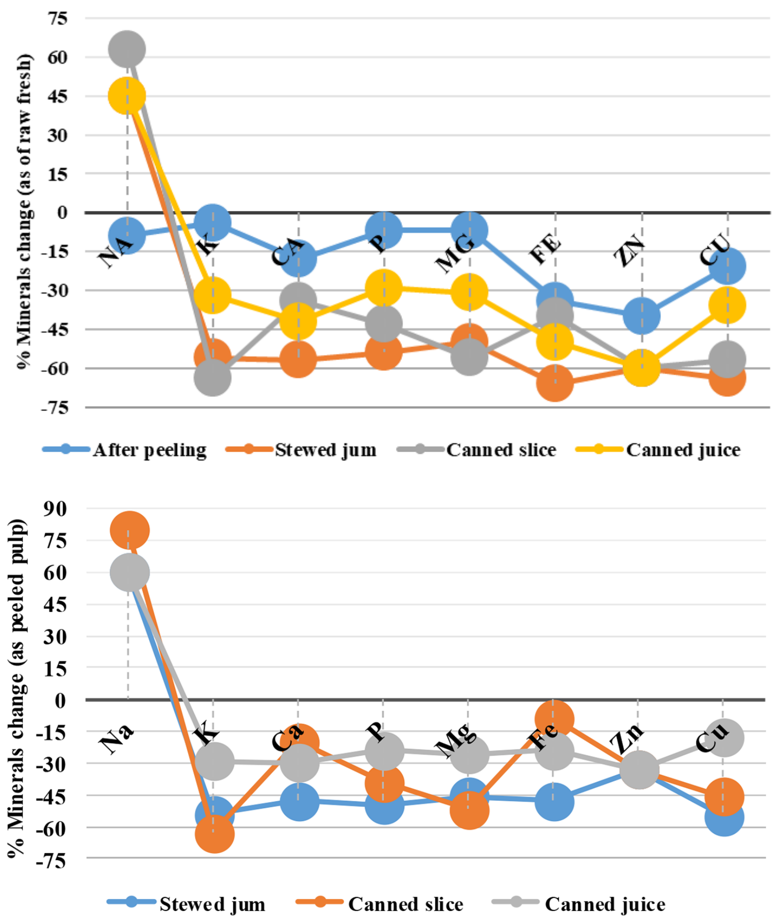

Figure 1. Minerals changing of apple products as affected by pre-processing and processing procedures

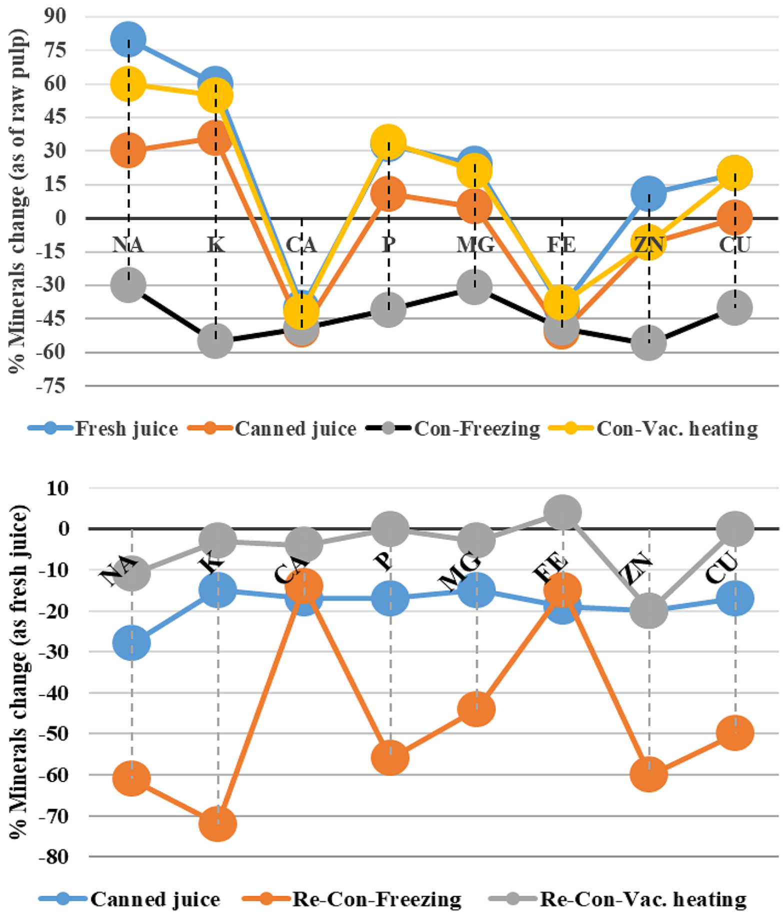

Figure 2. Minerals changing of orange products as affected by pre-processing and processing procedures

as pectin, protein, fiber, and/or insoluble salts) in the fruit pulps (Czech et al., 2020) showed that the calcium content in the peel was more than 50% higher than the calcium concentration in the pulp in all citrus fruits. As a result, the nutritional value of fruit is significantly diminished when this portion is removed.

It was possible to see that, in some cases, these pre-processing treatments had an impact on mineral loss, rather than processing itself. For example, although Fe was a more resistant mineral to leaching during processing, its leaching did not exceed 8 and 11% of its original content in canned peach and apricot halves (Table 6 and Figure 4, 5), whereas canned apple slices lost about 40% of the original Fe content that was found in it raw fresh (unpeeled) fruit, as shown in Figure 1, primarily due to the

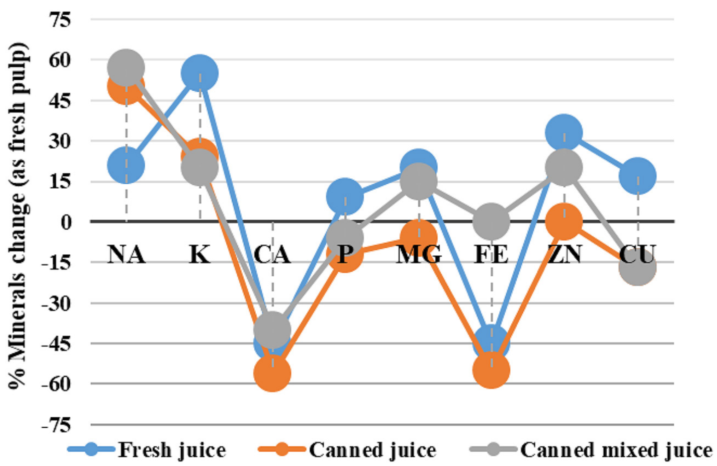

Figure 3. Minerals changing of grapefruit products as affected by pre-processing and processing procedures

Table 5. Minerals content of raw grapefruit and their processed products as affected by pre-processing and processing procedures

Minerals	Grapefruit				Mango			
	**Raw pulp	Fresh juice	Canned juice	* Canned mixed juice	*Raw pulp	Canned juice	Un-diluted	Re-const.
Mg /100g								
Na	1.4	1.7	2.1	2.2	7.1	8.8	8.8	3.6
K	234	362	290	281	189	143	141	111
Ca	16	8.8	7	9.6	16.2	12.6	12.0	9.7
P	16	17.5	14	15	18.6	13.0	13.7	10.7
Mg	10.4	12.5	9.8	12	20.4	15.6	15.7	11.4
Mg/kg								
Fe	4.0	2.2	1.8	4.0	5.0	3.2	3.8	2.3
Zn	0.3	0.4	0.3	0.6	2.2	1.6	1.8	1.4
Cu	0.6	0.7	0.5	0.5	1.2	0.8	0.8	0.6

Note: * Calculated based on the mineral content in raw pulps and fresh juice.

Table 6. Mineral contents of raw apricot, peach, and their processed products as affected by processing procedures

Minerals	Apricot							Peach		
	*Raw fresh	Canned juice	Canned halves	Stewed (jam)	Syrup (cont.)	**Dehydrated		*Fresh pulp	Canned halves	Stewed (jam)
						Whole	Sheet			
Mg /100g										
Na	1.0	2.1	2.7	0.6	2.6	6.0	7.1	1.5	1.8	1.2
K	281	201	151	134	199	866	989	225	135	118
Ca	17.2	11.6	14.1	8.3	12.8	78.2	94.7	7.6	6.7	3.2
P	21.3	14.8	14.2	11.1	15.9	89.7	118.5	20.1	13.8	9.8
Mg	12.2	8.4	6.6	6.6	9.3	56.6	62.5	6.9	4.3	3.3
Mg /kg										
Fe	3.7	2.7	3.3	1.8	2.7	18	22	5.0	4.6	2.5
Zn	0.6	0.4	0.4	0.3	0.4	2.7	3.3	2.0	1.5	1.0
Cu	1.2	0.8	0.8	0.6	0.8	3.7	4.9	5.0	3.6	2.7

Note: * Free from seeds;** The moisture content was 15%.

peeling effect. In comparison to canned peach halves, only 9% of the original Fe in raw, peeled apple (pulp) was lost by leaching during the preparation of apple slices. This observation was also evident in the Ca content, where the highest reduction of Ca by leaching did not exceed 14% of its content in fresh juice during the concentration of orange juice by freezing (processing) while juicing of orange pulp (pre-processing) resulted in the loss of 40% of original Ca content in the fresh pulp (Fig. 2). Accordingly, it is possible that the amount of Ca and Fe lost during pre-processing is greater than the amount lost by leaching during processing. Consequently, the preprocessing procedures have a noticeable impact on the minerals in the finished fruit products.

Minerals retention as a guideline of processing procedures

When the examined raw fruits underwent various processing techniques, they kept between 38 and 98% of their original Ca, P, Mg, Fe, Zn, and Cu contents, as shown in the previous tables. This retention could be decreased to 28% of the original K because, during several processing steps, leaching causes it to gradually disappear. This study has demonstrated how challenging it is to select a processing method for any processed fruit that will preserve all of the original minerals.

When the evaluated fruit products were thermally treated in the presence of excluded liquid media, minerals were often reduced either by leaching out (for the fruits) or by diluting (due to the addition

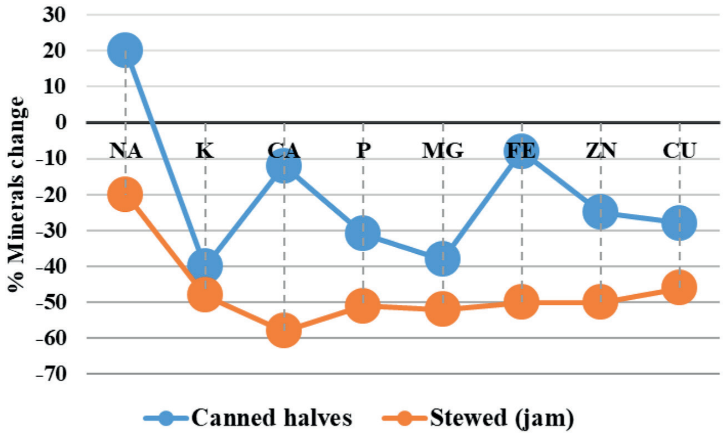

Figure 4. Minerals changing of peach products as affected by processing procedures

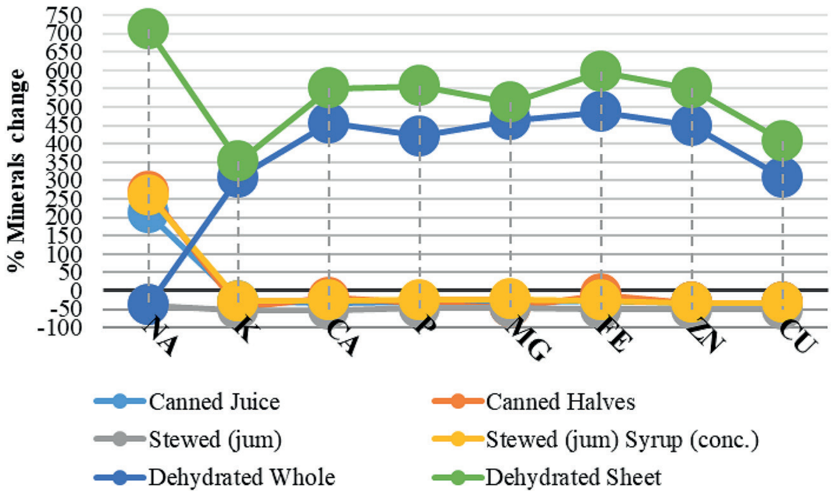

Figure 5. Minerals changing of processed apricots as affected by processing procedures

of sugar or sweaty solution during processing). This indicates that the method used in each processing operation is primarily responsible for the retention of minerals in the evaluated fruit products.

After the juice was canned, the orange and grapefruit juices still included around 75 to 83% of the minerals present in their fresh juices (Figures 2, 3), but the apricot, guava, and mango juices

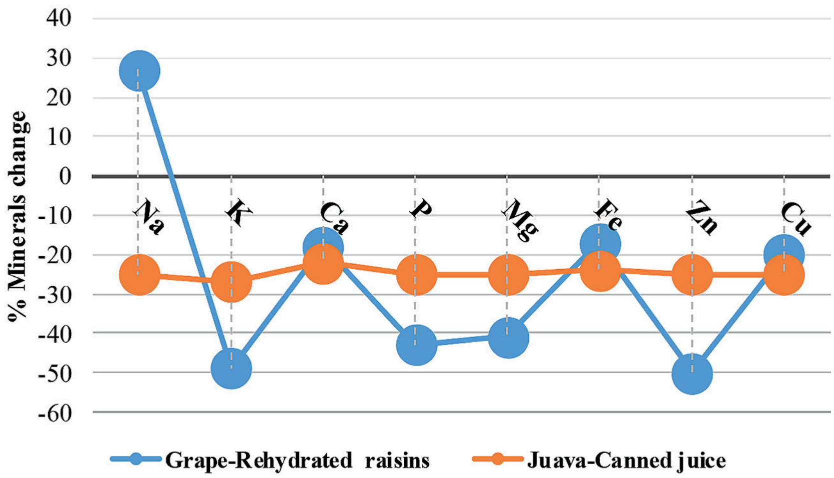

Figure 6. Minerals changing of processed grape and guava as affected by pre-processing and processing procedures

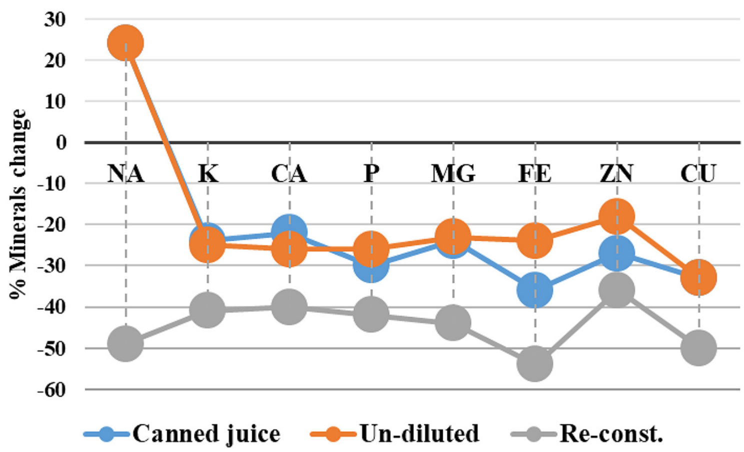

Figure 7. Minerals changing of processed mango as affected by processing procedures

still had about 67 to 78% of the minerals present in the comparable raw pulps (Figures 5, 6 and 7).

The dilution caused by the added sugar solution had an impact on the lowering of mineral content in canned fruit juices as well as in their raw counterparts. As a result, the different addition ratios of sugar solution may be attributed to the varying percentages of minerals maintained in the first group of canned juices in the second group, making the values for mineral retention directly proportional to these ratios.

The canned fruit parts (halves of apricot and peach; and slices of apple) contained fewer minerals than their raw ones. According to Tables 1, 6 and Figures 1, 4, 5, leaching from these canned fruit products resulted in the loss of 40–64% of the original potassium in the raw pulps, followed in decreasing order by Mg (38–56%), Cu (28–57%), P (31–43%), and Zn (25–60%). In turn, both Fe (8–40%) and Ca (12–34%) were minimally leached during such processing procedure. During the canning process, the heat conditions leached these minerals from fruit portions into the outer solution. The maximum K leaching was also noticed during the canning of vegetables, according to (Bhowmik et al., 2012; Cakmak et al., 2004).

Fruit juice concentration and fruit dehydration led to an increase in the mineral content. Therefore, it is done in their rehydrated fruits (to the original TS% in raw fruits) and reconstituted juices (as TSS% that is found in raw juice) to evaluate the level of mineral retention in these goods. In comparison to their fresh counterparts, the rehydrated fig and raisins (Table 7 and Figure 8) had reduced concentrations of all tested minerals, especially K, which was followed by P, Mg, and Zn before finally arriving at Fe and Ca. All of these minerals were likely dissolved during the pre-processing (blanching) of raw fruits in boiling water and lye-dipping, soaking in warmed sulfuring solution for 15 minutes,

Table 7. Minerals content of raw grape, guava, and fig, and their processed products as affected by pre-processing and processing procedures

Minerals	Grape			Guava		Fig			
	Raw fresh	Raisins		Raw fresh	Canned juice	Raw fresh	Stewed (jam)	Dehydrated	
		Dried	Re-hydrated					Dried	Re-hydrated
Mg/100g									
Na	1.5	5.8	1.9	4.0	3.0	32	23	94	24
K	173	411	89.0	287	209	240	133	640	156
Ca	12.4	60.8	10.2	23.3	18.1	35.1	18	105.4	29.8
P	20.0	68.6	11.4	42.0	31.6	22.4	11.6	77.6	17.8
Mg	6.4	24.0	3.8	13.1	9.8	20.4	9.8	71.8	16.8
Mg /kg									
Fe	4.1	11.9	3.4	9.0	6.8	6.0	6.0	0.3	23.7
Zn	0.4	1.3	0.2	0.8	0.6	1.0	1.0	0.5	6.0
Cu	1.0	4.0	0.8	0.4	0.3	1.0	1.0	0.5	4.2

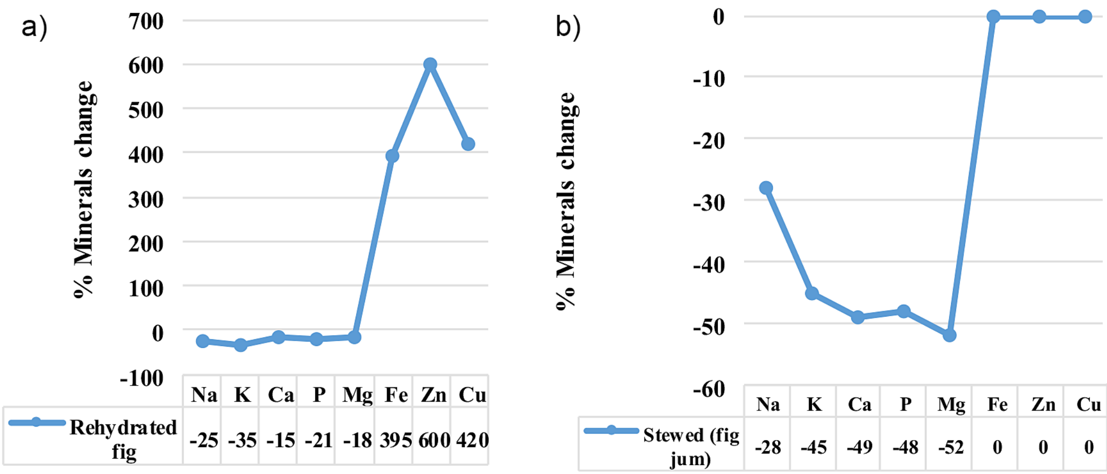

Figure 8. Minerals changing of processed fig as affected by processing procedures, (a) rehydrated fig, (b) stewed (fig jum)

dripping throughout the drying process, and dehydrating in warmed water for 30 minutes. When compared to the minerals leached during the canning of fruit sections, the minerals leached from dehydrated products of entire fruits were lower.

According to the findings released by (Bhowmik et al., 2012) various mineral salts can change chemical forms, such as being soluble or insoluble, in addition to being considerably influenced by leaching during some heat treatments.

The processes used with the concentration approach had a strong correlation with the retained minerals in concentrated orange juice. When compared to the reconstituted juice made by vacuum-heat concentration (Table 4), which kept considerably greater original minerals in raw juice, the reconstituted orange juice generated by the freeze-concentration procedure had a much lower retention of the initial minerals found in raw orange juice. This is because, during freeze concentration, water was removed from fresh orange juice by frequently centrifuging crushed frozen juice, which improved the leaching out of significant amounts of readily soluble mineral salts from orange juice, whereas during vacuum-heat concentration, water was removed by evaporation, where there is no possibility of mineral loss.

During the processing of jam, the sugars that were added to raw fruit pulps (1:1 w/w) were logically reduced in their mineral content in the final products. As seen in apple, peach, apricot, and fig jams (Tables 4, 6, and 7), they included almost 50% of all evaluated minerals in their raw forms. Additionally, it was discovered that the mineral content in apricot and mango syrup products (Tables 6 and 5) was only about 75% of what it had originally been, as a result of dilution from the addition of sugar solution to the fruit puree.

Apples, oranges, grapefruit, and grapes were among the fruit products the mineral changing of which was determined using two bases (Tables 4, 5, and 7). When the mineral retention was calculated based on the prepared raw fruits (after pre-processing), i.e., peeled fruit or fresh juices, this was done to study the actual reduction as affected only by processing per se. The mineral retention was calculated by ascribing to the original mineral content in their raw whole fruits to evaluate the total losses that occurred during pre-processing plus processing.

The effect of fruit type on mineral leaching extent during processing

The current findings demonstrated that the identical fruit products – which they produced using the same methods from various fruit types – did not exhibit equivalent value in their mineral leaching. This was seen in both dehydrated fruits and fruit pieces that had been canned. In comparison to canned apples (Table 4), which showed sensitivity to this process and preserved fewer minerals, canned peaches (Table 6) and canned apricot (Table 6) both demonstrated greater tolerance to the temperature conditions of the canning process. This was seen when the leaching of K, Mg, Zn, and Cu minerals was done.

More so than the dehydrated grape (Table 7, Figure 6, and 8), which demonstrated greater sensitivity to this technique, especially when the minerals of K, P, Mg, and Zn were taken into account, the dehydrated fig demonstrated greater resistance to leach their original minerals during dehydration conditions and retained higher minerals. The differences in internal structure that are inherent in the pulps of various fruit kinds that are identically processed by canning or dehydration may be related to the resistance or susceptibility of these fruit types to the thermal conditions associated with such processing. In turn, the extent to which they were affected by this processing depending on how resistant or sensitive they were to it. The conflict in the ratios of soluble: insoluble matters and the type of chemical compounds that combined metals in their pulps may be the cause of the effective role of particular inner structures on the mineral leaching degree of tested fruits that are identically processed. According to Davis (2006 and 2009), the effects of any processing treatments on food products rely not only on the techniques but also on the specific type of food being processed. This indicates that both the processing technique parameters and the type of processed fruits had an impact on the amount of leached minerals (or retention).

The changing of minerals by dilution during processing

While it had no impact on the degree of mineral retentions of the fruit products processed by stewing (jam production), syrup process, and juice canning, the variation of inner structure between tested fruit types plays a significant role in the extent of minerals leached during fruit canning and dehydration processing. All products from various fruit species displayed generally equal mineral reduction values after this processing, meaning that their minerals were similarly altered.

For instance, all examined fruits that were used to make jam (apple, peach, apricot, and fig) kept the same values (50%) of their original minerals as in raw pulps, regardless of the fruit type, as shown in Tables 4, 6, and 7. This observation was confirmed in the tested syrup products and canned juices made from various fruit juices, where regardless of the fruit utilized, their mineral uniformity varied as compared to their raw counterparts. This is because dilution brought on by the addition of sugar (during the stewing process) or sweating solutions caused the minerals to change during such processing (during syrup and juice canning processes). As a result, only processing techniques had an impact on their mineral retentions, which were proportionally correlated to the level of extra ratios. The sensitivity or resistance of the operated fruit varieties had no bearing on their mineral changes. There was no leaching of the minerals from these various fruit products (jams, syrups, and canned juices) because they were thermally treated without the addition of any water. The particular type discrepancies of the examined fruit types had an impact on the mineral changing of the fruit products that lost their minerals by leaching, in contrast, and these products did not exhibit comparable values of each mineral changing.

CONCLUSIONS

Depending on the applied processing techniques and specific fruit varieties, all processed fruit products lost 2–62% of their native minerals in initial raw fruit (increased to 72% for K by leaching). However, compared to other fruit products that were examined, fig, apricot, and orange products showed higher nutritional benefits as a source of minerals. The Fe and Ca contents were significantly reduced during pre-processing procedures (such as peeling fruit and extracting juice), whereas leaching during the processing itself had a much less impact. Leaching (during fruit cunning, fruit dehydration, and freeze-concentration of juice) or dilution were the two methods used to modify the mineral content of fruit during processing (addition of sugars during stewing and syrup process or addition of sweaty solution in canned juices). When equally handled, the fruits that lost their minerals by leaching did not exhibit equivalent values of mineral retention, whereas the fruits that changed their mineral contents through diluting did. Some minerals, such as K, Zn, Mg, Cu, and P, appeared more sensitive to leaching loss during the canning of fruits than others, who demonstrated resilience to leaching (such as Fe and Ca). The juice that was concentrated by vacuum-heating and the cooked fruit pulps that were treated by dehydrating in sheet form both preserved relatively higher concentrations of their initial minerals than their raw counterparts.

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REFERENCES

1. EFSA, 2017. Dietary reference values for nutrients summary report 2017 14. https://doi.org/10.2903/sp.efsa.2017.e15121
2. Adewusi, S.R.A., Ojumu, T.V., Falade, O.S. 1999. The effect of processing on total organic acids content and mineral availability of simulated cassava-vegetable diets. Plant Foods Hum. Nutr. 53, 367–380. https://doi.org/10.1023/A:1008081217786
3. Afshin, A., Sur, P.J., Fay, K.A., Cornaby, L., Ferrara, G., Salama, J.S., Mullany, E.C., Abate, K.H., Abbafati, C., Abebe, Z., Murray, C.J.L. 2019. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet, 393, 1958–1972. https://doi.org/10.1016/S0140-6736(19)30041-8
4. Alajil, O., Sagar, V.R., Kaur, C., Rudra, S.G., Sharma, R.R., Kaushik, R., Verma, M.K., Tomar, M., Kumar, M., Mekhemar, M., 2021. Nutritional and phytochemical traits of apricots (*Prunus Armeniaca* L.) for application in nutraceutical and health industry. mdpi.com. https://doi.org/10.3390/foods10061344
5. Amagloh, F., Food, E.N.A.J. 2012. Mineral nutrient content of commonly consumed leafy vegetables in northern Ghana. ajol.info.
6. Bhowmik, S., Datta, B.K., Saha, A.K., Kumar Datta, B., 2012. Determination of mineral content and heavy metal content of some traditionally important aquatic plants of tripura, India using atomic absorption spectroscopy. J. Agric. Technol., 8, 1467–1476.
7. Bjørklund G. 2013. The role of zinc and copper in autism spectrum disorders. Acta Neurobiol Exp, 73, 225-236.
8. Bonewit-West, K., Hunt, S., n.d. Today's Medical Assistant-E-Book: Clinical & Administrative Procedures 2019.
9. Bouhlali, E., Dine T., Derouich, M., Meziani, R., Bourkhis, B., Filali-Zegzouti, Y., Alem, C. 2020. Nutritional, mineral and organic acid composition of syrups produced from six Moroccan date fruit (P*hoenix dactylifera* L.) varieties. J. Food Compos. Anal., 93, 103591. https://doi.org/10.1016/J.JFCA.2020.103591
10. Bouhlali, E., Dine T., Derouich, M., Meziani, R., Bourkhis, B., Filali-Zegzouti, Y., Alem, C. 2020. Nutritional, mineral and organic acid composition of syrups produced from six Moroccan date fruit (*Phoenix dactylifera* L.) varieties. J. Food Compos. Anal., 93, 103591. https://doi.org/10.1016/J.JFCA.2020.103591
11. Briguglio, M., Hrelia, S., Malaguti, M., Lombardi, G., Riso, P., Porrini, M., Perazzo, P., Banfi, G., 2020. The central role of iron in human nutrition: from folk to contemporary medicine. https://doi.org/10.3390/nu12061761
12. Brzezińska-Rojek, J., Rutkowska, M., Brzezicha, J., Konieczka, P., Prokopowicz, M., Grembecka, M., 2022. Mineral composition of dietary supplements-analytical and chemometric approach. Nutrients 14, 106. https://doi.org/10.3390/NU14010106/S1
13. Cakmak, I., Torun, A., Millet, E., Feldman, M., Fahima, T., Korol, A., Nevo, E., Braun, H.J., Özkan, H. 2004. Triticum dicoccoides: An important genetic resource for increasing zinc and iron concentration in modern cultivated wheat. Taylor Fr., 50, 1047–1054. https://doi.org/10.1080/00380768.2004.10408573
14. Chasapis, C.T., Ntoupa, P.S.A., Spiliopoulou, C.A., Stefanidou, M.E. 2020. Recent aspects of the effects of zinc on human health. Arch. Toxicol., 94, 1443–1460. https://doi.org/10.1007/S00204-020-02702-9
15. Chen, J., Jiang, Y., Shi, H., Peng, Y., Fan, X., Li, C. 2020. The molecular mechanisms of copper metabolism and its roles in human diseases. Pflugers Arch. Eur. J. Physiol., 472, 1415–1429. https://doi.org/10.1007/S00424-020-02412-2
16. Chowdhury, M.A., Hossain, N., Kashem, M.A., Shahid, M.A., Alam, A. 2020. Immune response in COVID-19: A review. J. Infect. Public Health, 13, 1619–1629. https://doi.org/10.1016/J.JIPH.2020.07.001
17. Czech, A., Zarycka, E., Yanovych, D., Zasadna, Z., Grzegorczyk, I., Kłys, S. 2020. Mineral content of the pulp and peel of various citrus fruit cultivars. Biol. Trace Elem. Res., 193, 555–563. https://doi.org/10.1007/S12011-019-01727-1
18. Davis, D.R. 2006. Commentary on: "Historical variation in mineral composition of edible horticultural products". Journal of Horticultural Science & Biotechnology, 80, 660-667.
19. Davis, D.R. 2009. Declining fruit and vegetable nutrient composition: What is the evidence? HortScience, 44, 15–19. https://doi.org/10.21273/HORTSCI.44.1.15
20. Du, S., Neiman, A., Batis, C., Wang, H., Zhang, B., Zhang, J., Popkin, B.M., 2014. Understanding the patterns and trends of sodium intake, potassium intake, and sodium to potassium ratio and their effect on hypertension in China. Am. J. Clin. Nutr., 99, 334–343. https://doi.org/10.3945/AJCN.113.059121
21. Ekholm, P., Reinivuo, H., Mattila, P., Pakkala, H., Koponen, J., Happonen, A., Hellström, J., Ovaskainen, M.L. 2007. Changes in the mineral and trace element contents of cereals, fruits and vegetables in Finland. J. Food Compos. Anal., 20, 487–495. https://doi.org/10.1016/J.JFCA.2007.02.007
22. Fardet, A., Richonnet, C., Mazur, A. 2019. Association between consumption of fruit or processed fruit and chronic diseases and their risk factors: a systematic review of meta-analyses. Nutr. Rev., 77, 376–387. https://doi.org/10.1093/NUTRIT/NUZ004
23. Fratianni, F., Ombra, M.N., d'Acierno, A., Cipriano, L., Nazzaro, F. 2018. Apricots: biochemistry and functional properties. Curr. Opin. Food Sci., 19, 23–29. https://doi.org/10.1016/J.COFS.2017.12.006
24. Gergely, A., Papp, N., Stefanovitsné Bányai, É., Hegedűs, A., Rábai, M., Szentmihályi, K. 2014.

Assessment and examination of mineral elements in apricot (Prunus armeniaca L.) cultivars: A special attention to selenium and other essential elements.

25. Hussain A., Larsson H., Kuktaite R., Johansson E. 2010. Mineral composition of organically grown wheat genotypes: Contribution to daily minerals intake. Int. J. Environ. Res. Public Health, 7(9), 3442-3456. https://doi.org/10.3390/ijerph7093442
26. Jan, N., Anjum, S., Wani, S.M., Mir, S.A., Malik, A.R., Wani, S.A., Hussein, D.S., Rasheed, R.A., Gatasheh, M.K. 2022. Influence of canning and storage on physicochemical properties, antioxidant properties, and bioactive compounds of apricot (*Prunus armeniaca* L.) wholes, halves, and pulp. Front. Nutr., 9, 850730. https://doi.org/10.3389/FNUT.2022.850730
27. Khairunnisa, M., Nurcahyani, Y.D., Samsudin, M., Martiyana, C. 2022. The influence of my plate campaign to increase local fruit and vegetable consumption. IOP Conf. Ser. Earth Environ. Sci., 1024, 012081. https://doi.org/10.1088/1755-1315/1024/1/012081
28. Long S., Romani A.M. 2014. Role of cellular magnesium in human diseases. Austin J. Nutr. Food Sci., 2(10), 1051.
29. Miller D.D., Welch R.M. 2013. Food system strategies for preventing micronutrient malnutrition. Food Policy, 42, 115-128.
30. Monteiro C.A., Cannon G., Levy R., Moubarac J.-C., Jaime P., Martins A.P, Canella, et al. 2016. NOVA. The star shines bright. Food classification. Public health, 7(1-3).
31. Morgounov, A., Ferney Gó Mez-Becerra, H., Abugalieva, A., Dzhunusova, M., Yessimbekova, M., Muminjanov, H., Zelenskiy, Y. 2007. Iron and zinc grain density in common wheat grown in Central Asia. Springer 155, 193–203. https://doi.org/10.1007/s10681-006-9321-2
32. Ojwang, D., Nyankanga, R., J.I.J.F. 2021, undefined, 2021. Effects of processing and storage on the nutrient composition of green vegetable pigeonpea. Wiley Online Libr., 45. https://doi.org/10.1111/jfpp.15714
33. Orlando, P., Nartea, A., Silvestri, S., Marcheggiani, F., Cirilli, I., Dludla, P. V., Fiorini, R., Pacetti, D., Loizzo, M.R., Lucci, P., Tiano, L. 2022. Bioavailability study of isothiocyanates and other bioactive compounds of *Brassica oleracea* L. var. italica boiled or steamed: Functional food or dietary supplement? Antioxidants, 11, 209. https://doi.org/10.3390/ANTIOX11020209
34. Prasad A.S. 2014. Impact of the discovery of human zinc deficiency on health. J. Trace Elem. Med. Biol., 28, 357–363. https://doi.org/10.1016/J.JTEMB.2014.09.002
35. Rahman M.A, Ali M.A., Kamrul Hasan S.M., Sarker M. 2015. Effects of peeling methods on mineral content of potato and development of potato based biscuit. Int. J. Nutr. Food Sci., 4(6), 669-675.
36. Rickman, J., C.B. of the S. of F. and, 2007, undefined, 2007. Nutritional comparison of fresh, frozen, and canned fruits and vegetables II. Vitamin A and carotenoids, vitamin E, minerals and fiber. Wiley Online Libr., 87, 1185–1196. https://doi.org/10.1002/jsfa.2824
37. Rojas-Molina, I., Gutiérrez-Cortez, E., Bah, M., Rojas-Molina, A., Ibarra-Alvarado, C., Rivera-Muñoz, E., Del Real, A., Aguilera-Barreiro, M.D.L.A. 2015. Characterization of calcium compounds in opuntia ficus indica as a source of calcium for human diet. J. Chem. 2015. https://doi.org/10.1155/2015/710328
38. Shahat, M.S.I., El-badry, N., Abdel-Hameid, A.A., Ghanem, T.H., El-Sayed, G.A. 2016. Comparative study between the dried fruits by solar dryers with or without reflective mirrors as utilization of renewable solar energy and conventional dryers. Middle East journal of applied science, 6(3), 490-510.
39. Stern B.R., Solioz M., Krewski D., Aggett P., Aw T.C., Baker S., Crump K., Dourson M., et al. 2007. Copper and human health: Biochemistry, genetics, and strategies for modeling dose-response relationships. J. Toxicol. Environ. Heal. Part B Crit. Rev., 10, 157–222. https://doi.org/10.1080/10937400600755911
40. Stone M.S., Martyn L., Weaver C.M. 2016. Potassium intake, bioavailability, hypertension, and glucose control. Nutr., 8, 444. https://doi.org/10.3390/NU8070444
41. Székely, D., Furulyás, D., Stéger-Máté, M. 2019. Investigation of mineral and vitamin C contents in different parts of beetroots (*Beta vulgaris* L.). Not. Bot. Horti Agrobot. Cluj-Napoca, 47, 615–620. https://doi.org/10.15835/NBHA47311394
42. Teribia N., Buvé C., Bonerz D., Aschoff J., Goos P., Hendrickx M., Van Loey A., 2021. The effect of thermal processing and storage on the color stability of strawberry puree originating from different cultivars. LWT, 145, 111270. https://doi.org/10.1016/J.LWT.2021.111270
43. White, P.J., Bradshaw, J.E., Dale, M.F.B., Ramsay, G., Hammond, J.P., Broadley, M.R., 2009. Relationships between yield and mineral concentrations in potato tubers. HortScience, 44, 6–11. https://doi.org/10.21273/HORTSCI.44.1.6
44. Wu, J., Yuan, Y.X., Zhang, X.W., Zhao, J., Song, X., Li, Y., Li, X., Sun, R., Koornneef, M., Aarts, M.G.M., Wang, X.W. 2008. Mapping QTLs for mineral accumulation and shoot dry biomass under different Zn nutritional conditions in Chinese cabbage (*Brassica rapa* L. ssp. pekinensis). Plant Soil, 310, 25–40. https://doi.org/10.1007/S11104-008-9625-1/TABLES/5
45. Yahia, E.M., García-Solís, P., MaldonadoCelis, M.E. 2019. Contribution of fruits and vegetables to human nutrition and health. Postharvest Physiol. Biochem. Fruits Veg., 19–45. https://doi.org/10.1016/B978-0-12-813278-4.00002-6
46. Yeasmin, F., Rahman, H., Rana, S., Khan, J., Islam, N. 2021. The optimization of the drying process and vitamin C retention of carambola: An impact of storage and temperature. Wiley Online Libr., 45, 15037. https://doi.org/10.1111/jfpp.15037