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Effect of Some Different Drying Methods on the Chemical Analysis of Citrus By-Products.

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ABSTRACT

This study is aimed at determined the effect of some different drying methods (microwave, solar and oven drying) on the chemical analysis of selected citrus by-products was assessed by proximate and minerals analysis. From analyze the proximate analysis, the results proved that there are significant differences ($P<0.05$) between the moisture content in the samples dried using different drying methods. Consequences to the chemical composition of the samples include ash, protein, and fat. Results reflect that there are significant differences ($P<0.05$) between the different drying methods. The trend of the results in this study generally indicates that oven drying retains higher levels of crude protein than solar-drying. The crude fiber content different types of citrus peel as affected significantly ($P<0.05$) decreased to different drying methods. The result revealed that microwave drying procedure was the highest effect on the retention crude fiber content of different citrus peel type. The results revealed that the oven-drying resulted in an overall affected significantly ($P<0.05$) increase in lignin compared with solar and microwave drying. While the mineral determination gave the data Ca, K, Na and Mg were the predominant mineral elements in the different samples. Besides, the analysis showed that the potassium and calcium are the most abundant minerals of the selected citrus peels. The effect of some different drying methods on the minerals content of citrus by-products The results showed that the calcium (Ca) and zinc (Zn) content of the selected citrus peels were increased significantly ($P< 0.05$) by drying with the solar-dryer compared with control. The results clearly showed that there was significant ($P< 0.05$) reduction in the contents of the citrus peels samples under study when the three methods of drying were used.
Keywords: Citrus by-products, drying methods, chemical analysis, minerals analysis.

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INTRODUCTION

Major components of wet waste orange peels are water (80 wt %), soluble sugars, cellulose and hemicellulose, pectin and D-limonene, the major environmental problem associated with citrus peel is its highly fermentable carbohydrate content, which accelerates its degradation when not carefully managed (Grohmann *et al.*, 2012).

According to Rivas *et al.* (2008), the proximally analyzed orange peel waste contained 40.7% moisture, 7.39% ash, 1.85% fat, 6.4% lignin, and 7.8% crude fiber. The present reported findings is in accordance with earlier reported data from the scientists (Muhammad *et al.,* 2014) According to the USDA National Nutrient data base, the peel of some fruits contains considerable amounts of minerals and vitamins, especially in citrus fruits. The peel is a rich source of minerals such as calcium, selenium, manganese, zinc…etc. containing several folds more than that in its pulp. These constituents are considered to be essential components of functional foods. Many of these substances prevent to damage to cell membrane and other structures of neutralizing free radicals. (Zvaigzne *et al,* 2009).

Mineral content is a measure of the amount of specific inorganic components present within a food material. The concentrations of minerals in citrus peels in general are influenced by several factors that include environmental, processing methods and genetic factors (White and Broadley, 2005). With respect to environmental factors the mineral content could be attributed to the availability of these minerals in the soil. It is estimated that humans require at least 22 mineral elements for a healthy life (White and Broadley, 2005). Most of the conventional thermal treatments for, hot-air drying, vacuum drying and sun-drying are used for food preservation primarily intended to inactivate enzymes, deteriorative microorganisms and reduce water activity. However, high temperatures and long drying periods usually reduce the quality of the final product Avila and Silva (1999). It has been reported that many reactions can affect color during processing of fruits and their derivatives. The dehydration processes is an essential operation step used for reducing moisture content and moisture activities of citrus peels. Convective drying has been widely used for preserving food- stuff due to the low investment and operating cost. The effect of the air drying temperature on the technological properties and the antioxidant capacity of dried citrus skin was studied by several authors. According to Garau *et al*. (2007), dried orange skin exhibited higher technological properties when the drying process was carried out at relatively low temperatures, 40–50 °C.

The application of new technologies, like microwave, radio-frequency, infrared radiation and power ultrasound could reduce the drying time and preserve the quality of dried foodstuff. Microwave drying had achieved considerable attention to the recent past, gaining popularity because of its advantages over conventional heating such as reducing the drying time of biological material with small quality loss (Arslan and Özcan, 2010). Moreover, microwave application has been reported to improve product qualities, such as aroma and to result in faster and better rehydration compared with hot air drying process (Maskan, 2000). Most of the conventional thermal treatments for, hot-air drying, vacuum drying and sun-drying are used for food preservation primarily intended to inactivate enzymes, deteriorative microorganisms and reduce water activity. However, high temperatures and long drying periods usually reduce the quality of the final product Avila and Silva (1999). It has been reported that many reactions can affect color during processing of fruits and their derivatives.

This study is aimed at determined the effect of some different drying methods (microwave, solar and oven drying) techniques on the chemical analysis of selected citrus by-products was assessed by chemical and minerals analysis and compared with the fresh citrus by-products.

MATERIALS AND METHODS

Materials

Plant materials

A survey studies have been done on many of the companies and factories producing citrus juices and located in the vicinity of industrial areas and outside of this ocean. The results of this research show that the vast majority of these plants (more than 90%) produces waste citrus in liquid form a result of transactions technological conducted to extract the juice of them, where it's dealing enzymes to facilitate the process of extracting the juice from the fruit, along with it the treatment of thermal its leading not to the possibility of the use of such waste in researching tests as a result of a change in its composition. As a result of this trend has been to use the remnants of juice shops, along with factories that do not treat the waste enzymes. The wastes obtained were as follows,

Ripen and freshly oranges [*C.Valencia, C. Balady,* and Tangerine (*C. Reticulate*) peel was preparation for collection of the Laboratory of Food Science and Technology, Food Technology Department, Food Technology and Nutrition Division, National Research Centre (NRC).

Chemicals and Reagents:

All used chemicals and reagents were purchased from Sigma Chemical Co. (St. Louis, Mo, USA). All other chemicals and reagents used were of analytical grade. The used water was distilled using water distillation apparatus (D 4000).

Preparation of citrus peels:

Citrus peels were washed by distilled water then to peel off manual peeler and their edible portions were carefully separated. Fresh citrus peels were cut as cubes of 1 cm^3 before processing.

Technological treatments:

All of the tested samples of citrus peels were prepared dried on perforated trays by using the different drying methods as follows:

a) Control: fresh citrus peels.

b) Microwave-drying: Microwave ovens used in the present study, (Samsung, Model MF245), with oven cavity dimensions of 419 x 245 x 428 mm and operation frequency of 2.450 MHz, with a power source of: 230 V-50 Hz was used. The nominal microwave power out putting was 900 Ws, air temperature 40 ºC /6 min.

b) Solar-drying: under conditions as shown in table (1), where one layers of citrus peels was placed on stainless steel trays and dried at temperatures: 48 hrs at 40 °C, the trays were removed when the weight of citrus peels was being a constant.

c) Air oven-drying: The citrus peels was placed on stainless steel trays in one layer and then placed on the oven and dried at temperatures: 8 hs at 40 °C, the trays were removed when the weight of citrus peels were being constant.

Table 1: Solar -drying conditions of citrus peels

Drying conditions	Temperatures /ºC
Temperature inside the dryer	40 ºC
Total time for drying	48 hs
Ambient air temperature	19.4 ºC
Relative humidity	57 %
Relative humidity inside the dryer	10 %
Global solar radiation	845 W/m^2
Initial moisture content	88 %
Final moisture content	5 %

The dried citrus peels were milled using a blender (Braun KMM 30 mill), type 3045, CombiMax (Germany) to pass through 100 mesh screen sieve. The dried citrus peels were immediately packed in polyethylene bags and stored at 4 ± 1°C in a refrigerator until used.

Chemical analysis:

Chemical analysis of the citrus peel samples was evaluated, namely moisture, protein, ash, fats and fiber according to the methods described in the AOAC (2000). Their analyses were performed in triplicate. Average and standard deviation values are shown in the tables.

Determination of lignin:

Lignin contents were determined gravimetrically by acid hydrolysis (Aravantinos-Zafiris *et al*., 1994). 2 g (W1) of sample was boiled with 10 mL of 70% (w/w H_2SO_4) solution for 4 to 5 hrs in order to hydrolyze the cellulose and hemicellulose. The remaining suspension after the above treatment was filtered with hot water. Then 30 mL of 70% $H_2SO_4$was added into the mixture and the solid residue was then transferred to a pre-weighted dried porcelain crucible and dried at 105 °C for 24 hs and weight (W2). The residue was heated at 650 °C for 4 hs or until all carbon is eliminated. After cooling, it was weighting (W3) and lignin content (%) was determined.

$$(\%)\ \text{Lignin} = \frac{(W2) - (W3)}{(W1)} \times 100$$

Determination of minerals:

Standard of minerals:

Micro-elements, i.e. zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), cadmium (Cd) and lead (Pb) as well as macro-elements, i.e. Potassium (K), calcium (Ca), sodium (Na), magnesium (Mg) and phosphorus (P) were provided by (Merck, Darmstadt, Germany). The working standards were prepared for the individual stock solution (1000 mg/L).

Determination of micro-elements i.e. zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), cadmium (Cd) and lead (Pb) were determined according to the method of A.O.A.C (2000) using Atomic Absorption Spectrophotometer, Perkin-Elmer 2380, with flame atomization (air-acetylene) 60-20, equipped with a 10cm burner, was used for the flame atomic absorption measurement of the metals. Maximum absorbance was obtained by adjusting the cathode lamps at specific slit width and definite wave length as recommended by the method as follows: 0.7, 213.9 nm (Zn); 0.2, 248.3 nm (Fe); 0.7, 324.8 nm (Cu); 0.2, 279.5 nm (Mn); 0.7, 357.9 nm (Cd) and 0.7, 283.3 nm (Pb), respectively. The flame photometer was applied for macro-elements: potassium (K), calcium (Ca), sodium (Na) and magnesium (Mg) determination according to the methods described by Pearson (1976). While Spectro photometric method was used for determination of the phosphorus (P) content with the tested samples using ammonium molybdate as outlined in the A.O.A.C (2000).

Statistical analysis:

The data obtained from study were statistically subjected to analysis of variance (ANOVA) and means separation was by Snedecor and Cochran (1980). The least significant difference (L.S.D) value was used to determine significant differences between means and to separate means at $p< 0.05$ using SPSS package version 15.0.

RESULTS AND DISCUSSION

Effect of some different drying methods of the chemical composition of citrus peel:

Chemical composition of the samples that have been dried using different drying methods was estimated, which led to a significant effect on the chemical composition of the samples as the primary goal of the drying process is to reach the absolute minimum of moisture content and that, take into account the lack of burning samples, which led to be the endpoint of each method of drying is different from the other, so the moisture content in the samples resulting from each drying method may be different from the other. Table 2 proved that there are significant differences ($P<0.05$) between the moisture content in the samples dried using different drying methods, whereas the solar-drying had the less percentage of moisture followed by drying using a microwave, while comes drying using the air oven ranked last (Table 2). The moisture content of fresh samples varied from 61.58±0.43 % in Valencia orange to 85.99±0.07 in Balady orange, while it was 67.98±0.14 % in Tangerine. The effect of heating of samples led to the rapid occurrence of burn and therefore, we had to which led to contain a higher percentage of moisture in all samples especially, air oven dried samples which had the highest amount of moisture compared to other drying methods (exp.: it was 7.83±0.03 % in oven drying Valencia orange, while it was 6.03±0.14 % and 7.98±0.08 % in solar and microwave, respectively).

Table 2: Moisture content of citrus peel as affected by some different drying methods (% w/w)

Sample types	Control	Microwave- drying	Solar-drying	Air oven-drying	L.S.D at 5 %
C. Valencia	61.58^{a}±0.43	7.98^{c}±0.09	6.03^{d}±0.14	7.83^{b}±0.03	0.21
C. Balady	65.99^{a}±0.07	7.04^{c}±0.05	6.35^{d}±0.09	7.66^{b}±0.03	0.11
Tangerine (*C. Reticulate*)	67.98^{a}±0.14	7.19^{d}±0.02	8.23^{c}±0.09	9.99^{b}±0.14	0.21

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within rows with different letters are significantly different (P < 0.05).

The solar dried sample had the least moisture content probably due to the shielding effect that the equipment has on the sample preventing rehydration by relative humidity in air (Abioye *et al*., 2014).

Consequences of the chemical composition of the samples include ash, protein, and fat (Tables 3, 4, and 5). Results reflect that there are significant differences (P<0.05) between the different drying methods, whereas, increased rates of these components decrease moisture contents of the samples and vice versa. For exp.: ash content of Valencia orange varied from 4.52±0.02 % in solar -drying to 4.43±0.04 % and 4.22±0.03 % in oven and microwave drying, respectively comparing to control samples (fresh) 1.68 ±0.03 % (Table 3).

The variation in ash contents also depends on plant species, geographical origins, their method of mineralization, as well as effect of food processing by drying (Sànchez-Machado *et al*., 2004).

While protein content was 4.7±0.01 % in solar -drying to 5.59±0.34 % and 5.59 ±0.14 % in oven and microwave drying, respectively comparing to control sample 2.37±0.09 % (Table 4). Protein helps in building and maintaining all tissues in the body, forms an important part of enzymes, fluids and hormones of the body and also helps form antibodies to fight infection and Supplies energy (Jonhson, 1996).

The trend of the results from this study generally indicates that the oven drying retains higher levels of crude protein than solar-drying. This may be due to the fact that that solar–dried vegetables are prone to dust and dirt contamination, attacks insects, and re-wetting of the drying vegetables by rain (Keding *et al*. 2007), which might affect the level of protein in them.

Fat content of Valencia orange was 1.65±0.17 %, 1.16±0.03 % and 2.13±0.03 % in solar, oven and microwave drying, respectively comparing to fresh sample, 0.71±0.02 % (Table 5). These significant differences (P<0.05) between treatments reflect the effect of drying methods of proximate composition. Similarly, **Hassan *et al*. (2007)** reported that oven drying lowers lipid content.

Table 3: Ash content of citrus peel as affected by some different drying methods (% w/w)

Sample types	Control	Microwave- drying	Solar-drying	Air oven-drying	L.S.D at 5 %
C.Valencia	1.68^{d}±0.03	4.22^{c}±0.03	4.52^{a}±0.02	4.43^{b}±0.04	0.06
C. Balady	1.54^{d}±0.11	4.70^{a}±0.01	4.23^{b}±0.03	4.18^{c}±0.04	0.15
Tangerine (*C. Reticulate*)	1.15^{d}±0.10	3.60^{b}±0.03	3.60^{a}±0.12	3.35^{c}±0.02	0.15

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within rows with different letters are significantly different (P < 0.05).

Table 4: Protein content of citrus peel as affected by some different drying methods (% w/w)

Sample types	Control	Microwave- drying	Solar-drying	Air oven-drying	L.S.D at 5 %
C.Valencia	2.37[b]±0.09	5.59[a]±0.14	4.7[a]±0.012	5.59[a]±0.34	0.011
C. Balady	3.09[c]±0.13	5.88[a]±0.16	5.72[a]±0.08	4.95[b]±0.05	0.21
Tangerine (*C. Reticulate*)	2.26[d]±0.13	7.13[b]±0.21	8.23[a]±0.12	6.8[c]±0.17	0.30

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within rows with different letters are significantly different (P < 0.05).

Table 5: Fat content of citrus peel as affected by some different drying methods (% w/w)

Sample types	Control	Microwave- drying	Solar-drying	Air oven-drying	L.S.D at 5 %
C.Valencia	0.71[d]±0.02	2.13[a]±0.05	1.65[b]±0.17	1.16[c]±0.03	0.17
C. Balady	0.83[d]±0.02	2.62[a]±0.04	1.57[b]±0.10	1.25[c]±0.04	0.11
Tangerine (*C. Reticulate*)	1.07[d]±0.07	1.73[c]±0.04	1.86[b]±0.03	2.08[a]±0.04	0.09

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within rows with different letters are significantly different (P < 0.05).

The crude fiber content of dried samples of lipid extraction analyzed by using acid digestion and alkali digestion and the result was shown in Table 6 indicated that fiber content in different types of citrus peel (Orange *C. Valencia*, Orange *C. Balady,* and Tangerine *C. Reticulate* as affected significantly (P<0.05) decreased to different drying methods (microwave, solar and air oven drying).

Results indicated that crude fiber levels of different samples are quite a variable among the different type of the samples source. The highest value of fiber content was detected in *C. Valencia*, followed by *C. Balady,* and Tangerine *C. Reticulate*, which recorded 13.80, 13.22 and 11.30 % dw, respectively. These levels were decreased to dried methods. In orange *C. Valencia*, crude fiber content recorded 12.93, 11.18 and 10.24 % dw, respectively with dried by microwave, solar and air oven methods, respectively. The corresponding values of orange *C. Balady* was 10.44, 9.20 and 8.89 % dw, respectively. With respect to Tangerine *C. Reticulate* crude fiber content were 10.78, 9.93 and 8.75 % dw, respectively.

Table 6: Crude fiber content of citrus peel as affected by some different drying methods (% dw)

Sample types	Control	Microwave- drying	Solar-drying	Air oven-drying	L.S.D at 5 %
C.Valencia	13.80[a]±0.51	12.93[b]±0.02	11.18[c]±0.74	10.24[d]±0.38	0.92
C. Balady	13.22[a]±0.56	10.44[b]±0.02	9.20[c]±0.02	8.89[d]±0.03	0.53
Tangerine (*C. Reticulate*)	11.30[a]±0.59	10.78[b]±0.02	9.93[c]±0.03	8.75[d]±0.02	0.56

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within rows with different letters are significantly different (P < 0.05).

The result revealed that microwave drying procedure was the highest effect on the retention crude fiber content of different citrus peel type followed by solar and air oven methods. Additionally, the higher drying temperatures the lower crude fiber content was found. These may be due to the degradation of other fiber such as cellulose or hemicelluloses during the drying process hence reduced the crude fiber content of dried sample (Nilnakara *et al*., 2009)

Effect of some different drying methods of the lignin content of citrus peel:

Data in Table 7 proved the levels of lignin in different types of citrus by-products (Orange *C. Valencia*, Orange *C. Balady*, and Tangerine *C. Reticulate*) and their affected by different drying methods (microwave, solar and oven drying). Results indicated that lignin concentrations of different samples are quite a variable among the different type of the samples source. The highest value of lignin was detected in Orange *C.*

Valencia, followed by Orange *C. Balady,* and Tangerine *C. Reticulate*, which recorded 6.25, 5.43, and 4.75, respectively.

Table 7: Lignin content of citrus peel as affected by some different drying methods (% dw)

Sample types	Control	Microwave- drying	Solar-drying	Air oven-drying	L.S.D at 5 %
C .Valencia	6.25^b ±0.03	5.99^c ±0.02	5.29^d ±0.02	8.54^a ±0.03	0.02
C. Balady	5.43^b ±0.03	5.38^c ±0.02	4.59^d ±0.03	7.92^a ±0.03	0.02
Tangerine (*C. Reticulate*)	4.75^b ±0.03	4.13^c ±0.03	3.78^d ±0.02	6.16^a ± 0.02	0.02

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within rows with different letters are significantly different (P < 0.05).

In orange *C. Valencia,* lignin content recorded 8.54, 5.29 and 5.99 %, respectively compared with control with dried by oven, solar and microwave drying methods, respectively. The corresponding values of orange *C. Balady* was 7.92, 4.59 and 5.38 % compared with control with dried by oven, solar and microwave drying methods, respectively. With respect to Tangerine *C. Reticulate* lignin content levels were 6.16, 3.78 and 4.13 % compared with control with dried by oven, solar and microwave drying methods, respectively. The results revealed that the oven drying procedure was the highest effect on the retention lignin content of different citrus by types followed by microwave drying methods.

The relatively low content of lignin about 3.23-5.75 % in peel samples indicated the absence of secondary wall of orange tissues (Carme Garau *et al*., 2007). Solar- drying exposes the materials to ultra violet radiation, which react with peel constituents to reduce lignin (Dzowela *et al*., 1995).

Minerals content of citrus peel (mg/100g DM):

Table 8 shows the minerals content (Ca, K, Na, Mg, P, Zn, Fe, Cu, Mn, Cd and Pb) of citrus by-products (Orange *C. Valencia*, Orange *C. Balady*, and Tangerine *C. Reticulate*) peels. As shown in Table 8 Ca, K, Na and Mg were the predominant mineral elements in the Orange *C. Valencia*, Orange *C. Balady*, and Tangerine *C. Reticulate*) peels. On the other hand, the potassium (K) and calcium (Ca) have steady contents whatever the type of peels. Besides, the analysis showed that the potassium and calcium is the most abundant minerals of the citrus peels.

Orange *C. Valencia* presents the significant (P< 0.05) highest amount of K (206.38 mg/100g), Ca (158.21 mg/100g), Mg (198.73 mg/100g) and Fe (34.32 mg/100g). Indeed, from many studies, a high proportion of potassium content is related to its assimilation or absorption by tissues. Thus, the great content of the citrus peels may have resulted from its abundance in the tissues of the orange (Wastowski *et al*., 2013).

Potassium records an important nutritious role in any organism. Intake of higher potassium content and sodium less could prevent the hypertension, source of the cerebral vascular damages and the heart diseases (Cook and Obarzanek, 2009). It's the main intracellular mineral. It takes part in the muscular activity and to the heart muscular. A dietary with high potassium content of favourable to the bone healthy thanks to its alkaline effect (ANONYME, 2010).

The calcium proportion is lower than that potassium. One of the main benefits from calcium related to interactions between cells walls. Therefore, it ensures the cells structure by hard cementing them. Calcium is a cellular component and regulator of the nervous excitability (Morschner, 1986). It's also a factor of ethylene synthesis during the fruits ripening (Morad, 1996).

The level of Ca was high in all samples. This is important for humans given its role in bone and tooth development (Oscan and Haciseferog¢cullari, 2007). Furthermore, Ca may be used for the prevention and treatment of hypertension, since it stabilizes vaso constriction. In combination with other similar ions such as Na^+, K^+, and Mg^{2+}, Ca^{2+} , provides an ionic balance for the vascular membrane, promoting vaso-relation and a reduction in blood pressure (Houston, 2005). Mg and K are cofactors for many enzyme reduction (Oscan and Haciseferog¢cullari, 2007).

Iron (Fe) is necessary for the formation of hemoglobin and also plays an important role in oxygen and electron transfer in human body (Mahapatra *et al.,* 2012) and normal functioning of the central nervous system and in the oxidation of carbohydrates, proteins and fats (Abbasi *et al.,* 2009). The observation of anemia in Fe deficiency may probably be related to its role in facilitating iron absorption and in the incorporation of iron into hemoglobin (FAO/WHO, 1984).

Sodium (Na) plays an important role in the transport of metabolites. High sodium intake has been proved to increase high blood pressure (Paul, 2004). The ratio of K/K in any food is an important factor of prevention of hypertension arteriosclerosis, with K depresses and Na enhances blood pressure.

Phosphorus (P) is an essential nutrient for all animals too. Deficiency in phosphorus is the most widespread of all the mineral deficiencies effecting livestock. Phosphorus must be balanced with the animal diet of adequate Ca and vitamin D for growth, reproduction, gestation, and lactation (Phosphorus in Animal Nutrition, 1999).

The positive impact on zinc (Zn) supplementation on the growth of some stunted children, and on the prevalence of selected childhood diseases such as diarrhea, suggests that zinc deficiency is likely to be a significant public health problem, especially in developing countries (Osendarp *et al.,* 2003).

Copper (Cu) play an important role in the health of individuals, infect their role is as important as that of vitamins. It is essential to maintain the required level of trace elements in the human body (Baptist *et al*., 1999).

Fortunately, results of the current study (Table 8) showed that the level of cadmium (Cd) was detected in a low concentration of orange Valencia were (0.22 mg/100g), respectively, while was not detected of orange Balady and Tangerine (*C. Reticulate*). Elements like lead (Pb) was also detected in a very low concentration of all of the analyzed citrus peels samples were orange Balady (0.03 mg/100g), followed by orange Valencia and Tangerine (*C. Rreticulate*) was (0.02 mg/100g). This means that the Cd and Pb elements were not accumulated in the plant. These concentrations are low when compared with the acceptable daily intake of 10 mg/kg (WHO, 1996). Cd and Pb cause both acute and chromic poisoning, and also pose adverse as the effect on kidney, liver, vascular and immune systems (Sheded *et al*., 2009). The elements manganese (Mn) in the present study was not detected in any of the analyzed citrus peels samples. These mean that the (Mn) were not accumulated in the plant.

The citrus peels can serve as source of valuable nutrients required for normal functioning as the body system. The utilization of these peels will enhance conversion of waste to wealth. It will also contribute positively to solid waste management and cleaner environments.

Table 8: Minerals content of citrus peels (mg/100g DM)

Sample types	Ca	K	Na	Mg	P	Zn	Fe	Cu	Mn	Cd	Pb
C. Valencia	158.21[a] ±1.01	206.38[a] ±2.00	138.16[b] ±2.00	198.73[a] ±1.99	31.24[b] ±2.00	8.22[b] ±1.00	34.32[a] ±0.02	1.03[b] ±0.02	ND	0.22[b] ±0.02	0.02[c] ±0.01
C. Balady	140.21[c] ±2.01	203.58[ab] ±2.01	121.18[c] ±0.99	126.75[c] ±2.01	22.31[c] ±1.08	4.41[d] ±0.02	12.81[b] ±0.02	0.98[c] ±0.02	ND	ND	0.03[b] ±0.01
Tangerine (*C.Reticulate*)	151.22[b] ±1.77	196.03[c] ±2.03	111.38[d] ±2.00	121.25[d] ±1.03	17.73[d] ±1.03	6.38[c] ±0.02	9.48[c] ±0.02	0.33[d] ±0.02	ND	ND	0.02[c] ±0.01
L.S.D at 5%	2.92	3.77	3.39	3.38	3.39	0.94	2.94	1.88	-	1.33	0.73

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within columns with different letters are significantly different ($P < 0.05$).
-ND: Non Detection.

Effect of some different drying methods of the minerals content of citrus peel:

Tables 9, 10and 11 show the effect of some different drying methods of the minerals content of citrus by-products (Orange *C. Valencia*, Orange *C. Balady*, and Tangerine *C. Reticulate*), respectively. The results showed that the calcium (Ca) contents of the Orange *C. Valencia*, Tangerine *C. Reticulate*, and Orange *C. Balady* peels were increased significantly (P< 0.05) by drying with the solar-dryer were (161.28, 154.33, and 143.25 mg/100g), respectively compared with control. This indicates that treatments solar-drying improved calcium content of the citrus peel, followed by oven-drying were (157.18, 153.28, and 142.31 mg/100g) in Orange *C. Valencia,* Tangerine *C. Reticulate*, and Orange *C. Balady* peels, respectively.

Table 9: Minerals content of citrus peel (Orange C. Valencia) as affected by some different drying methods (mg/100g DM)

Sample types	Ca	K	Na	Mg	P	Zn	Fe	Cu	Mn	Cd	Pb
Control	158.21^{ab} ±0.02	206.38^{a} ±2.02	138.16^{a} ±2.02	198.73^{a} ±2.00	31.24^{a} ±1.03	8.22^{d} ±0.03	34.32^{a} ±0.02	1.03^{b} ±0.02	ND	0.22	0.02
Microwave-drying	151.16^{c} ±1.03	205.31^{a} ±2.00	137.11^{a} ±2.00	197.20^{ab} ±2.02	30.17^{b} ±1.07	8.97^{c} ±0.02	34.02^{b} ±0.02	1.54^{a} ±0.02	ND	ND	ND
Solar-drying	161.28^{a} ±1.94	200.18^{b} ±2.01	133.21^{b} ±1.09	192.11^{c} ±2.00	28.31^{d} ±1.09	10.77^{a} ±0.03	32.15^{d} ±0.02	0.87^{d} ±0.02	ND	ND	ND
Air oven-drying	157.18^{b} ±2.00	203.27^{ab} ±2.06	135.18^{ab} ±2.00	194.71^{bc} ±2.07	29.17^{c} ±1.32	9.13^{b} ±0.02	33.23^{c} ±0.02	0.93^{c} ±0.02	ND	ND	ND
L.S.D at 5%	3.36	4.32	3.39	3.77	1.28	2.55	2.94	0.02	-	-	-

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within columns with different letters are significantly different (P < 0.05).
-ND: Non Detection.

Table 10: Minerals content of citrus peel (Orange C.Balady) as affected by some different drying methods (mg/100g DM)

Sample types	**Ca**	**K**	**Na**	**Mg**	**P**	**Zn**	**Fe**	**Cu**	**Mn**	**Cd**	**Pb**
Control	140.21^{c} ±2.09	203.58^{a} ±3.0	121.18^{a} ±1.99	126.75^{a} ±3.02	22.31^{a} ±2.0	4.41^{d} ±0.02	12.81^{a} ±1.02	0.98^{a} ±0.02	ND	0.22	0.03
Microwave-drying	139.18^{d} ±2.0	202.19^{b} ±1.99	120.23^{b} ±2.0	125.20^{b} ±2.03	21.96^{b} ±1.0	4.93^{c} ±0.02	12.15^{ab} ±0.02	0.97^{b} ±0.02	ND	ND	ND
Solar-drying	143.25^{a} ±1.98	200.75^{d} ±2.0	117.51^{d} ±2.0	123.17^{d} ±3.15	20.15^{d} ±3.0	6.47^{a} ±0.02	10.77^{c} ±0.02	0.95^{d} ±0.02	ND	ND	ND
Air oven-drying	142.31^{b} ±2.0	201.87^{c} ±1.98	119.83^{c} ±2.0	124.24^{c} ±3.02	21.24^{c} ±2.0	5.98^{b} ±0.02	11.38^{bc} ±0.02	0.96^{c} ±0.02	ND	ND	ND
L.S.D at 5%	2.33	3.15	2.38	2.44	1.32	1.04	1.16	0.02	-	-	-

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within columns with different letters are significantly different (P < 0.05).
-ND: Non Detection.

Table11: Minerals content of citrus peel Tangerine (*C. Reticulate*) as affected by some different drying methods (mg/100g DM)

Sample types	**Ca**	**K**	**Na**	**Mg**	**P**	**Zn**	**Fe**	**Cu**	**Mn**	**Cd**	**Pb**
Control	151.22^{c} ±3.0	196.03^{a} ±2.02	111.38^{a} ±2.73	121.25^{a} ±3.0	17.73^{a} ±2.0	6.38^{d} ±0.02	9.48^{a} ±0.02	0.33^{a} ±0.02	ND	ND	0.02
Microwave-drying	150.18^{d} ±2.01	195.32^{b} ±2.0	110.87^{b} ±2.0	120.77^{b} ±3.0	16.48^{b} ±2.0	6.87^{c} ±0.03	8.82^{b} ±0.02	0.32^{b} ±0.02	ND	ND	ND
Solar-drying	154.33^{a} ±2.09	192.93^{d} ±2.0	108.16^{d} ±2.0	118.43^{d} ±2.0	14.97^{d} ±2.0	8.97^{a} ±0.02	7.83^{d} ±0.02	0.29^{d} ±0.02	ND	ND	ND
Air oven-drying	153.28^{b} ±3.0	194.48^{c} ±2.0	109.33^{c} ±2.0	119.24^{c} ±3.0	15.39^{c} ±2.0	7.39^{b} ±0.02	8.45^{c} ±0.02	0.31^{c} ±0.02	ND	ND	ND
L.S.D at 5%	2.54	2.29	2.33	2.41	1.18	1.04	1.02	0.02	-	-	-

-All values are means of triplicate determinations ± standard deviation (SD).
- Means within columns with different letters are significantly different (P < 0.05).
-ND: Non Detection.

This results are in agreement with those reported by (Abioy *et al*., 2014), who reported that the calcium content of baabab leaves were increased significantly by drying with the solar-dried samples had the highest increase in the metal in with incremental values.

In the same trend solar-drying had the significant ($P< 0.05$) highest zinc value were (10.77, 8.97 and 6.47 mg/100g) in Orange *C. Valencia,* Tangerine *C. Reticulate* and Orange *C. Balady*, respectively. The processing methods had an advantage in improving zinc quality of citrus peels, which showed that it will contribute more to this nutrient than other samples.

The results from Tables 9, 10 and 11 indicated that potassium (K) content of Tangerine *C. Reticulate*, *C.*, Orange *C. Valencia* and Orange *C. Balady* peels were reduced significantly ($P< 0.05$) by drying with the solar-dryer were (192.93, 200.18 and 200.75 mg/100g), respectively compared with control.

The results from Tables 9, 10 and 11 proved that the solar-dryer were reduced significantly ($P< 0.05$) levels of Na, Mg, P, Fe and Cu were detected of the analyzed all citrus peel samples. Na content was (108.16, 117.51, and 133.21 mg/100g) in Tangerine *C. Reticulate*, Orange *C. Balady,* and Orange *C. Valencia* peels, respectively compared with control. Sodium (Na) was one of the minerals that registered losses exceeding 30 % probably due the fact that it is higher water soluble.

Magnesium (Mg) contents of Tangerine *C. Reticulate*, Orange *C. Balady,* and Orange *C. Valencia* peels were (118.43, 123.17 and 192.11 mg/100g), respectively compared with control.

The levels of phosphorus (P) content were (14.97, 20.15, and 28.31 mg/100g) in Tangerine *C. Reticulate*, Orange *C. Balady*, and Orange *C. Valencia* peels, respectively compared with control.

The iron (Fe) contents of Tangerine *C. Reticulate*, Orange *C. Balady,* and Orange *C. Valencia* peels were (7.83, 10.77 and 32.15 mg/100g), respectively compared with control.

The concentration of copper (Cu) was (0.29, 0.87 and 0.95 mg/100g) in Tangerine *C. Reticulate*, Orange *C. Valencia,* and Orange *C. Balady,* peels, respectively.

On the other hand, in the present study in Tables 9, 10 and 11 proved the elements Mn, Cd and Pb were not detected in any of the all analyzed citrus peels samples when the three methods of drying were used. The results clearly showed that there was significant ($P< 0.05$) reduction in the nutrient contents of the citrus peels samples under study when the three methods of drying were used. The level of nutrient content varies and depends on the type of citrus and method of drying. The reduction in the nutrient content may be due to the nature and sensitivity of the nutrient to the level of heat of the drying process.

CONCLUSION

The level of components content varies and depends on the type of citrus and method of drying. The reduction in this content may be due to the nature and sensitivity of the components to the level of heat during the drying process. This studied show that citrus by- products contained high amount of fiber, lignin and minerals. This suggested that peel which is most common and primary agro waste part of citrus fruits has shown the highest values for all the important parameters tested i.e. and they may serve as good nutraceutical sources. These materials, otherwise waste can be used as potential source of antioxidants for industrial application also.

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