

Influences of Juice Extraction and Drying Methods on the Chemical Analysis of Lemon Peels

Azza A. Abou-Arab, Marwa H. Mahmoud, Ferial M. Abu-Salem

Abstract—This study aimed to determine the influence of some different juice extraction methods (screw type hand operated juice extractor and pressed squeeze juice extractor) as well as drying methods (microwave, solar and oven drying) on the chemical properties of lemon peels. It could be concluded that extraction of juice by screw type and drying of peel using the microwave drying method were the best preparative processing steps methods for lemon peel utilization as food additives.

Keywords—Lemon peel, extraction of juice methods, chemical analysis.

I. INTRODUCTION

CITRUS fruits are the most important source of bioactive compounds which possess antioxidants properties such as phenolic, flavonoids, ascorbic acid, carotenoids, and pectin's as well as the essential minerals such as calcium, selenium, manganese, zinc etc.. [1]-[3]. Epidemiological studies on dietary citrus flavonoids showed that it is capable of reducing the risk of coronary heart disease, chronic diseases [4] and is attracting more attention not only due to antioxidant properties, but also anti-carcinogenic and anti-inflammatory activities as a result of their lipid anti-peroxidation effects [5]. According to the USDA National Nutrient information base, the peel of some fruits contains right amounts of minerals and vitamins, particularly citrus fruits. Several of these substances have the ability to prevent the damage of cell membrane and neutralize free radicals. Zvaigzne et al. [6] reported that citrus peels could be exploited in pharmaceutical and food application due to their high content of flavonoids.

Most of the traditional thermal treatments for, hot-air drying, vacuum drying, sun-drying, microwave drying and solar drying are used for food preservation primarily supposed to inactivate enzymes, deteriorative microorganisms and reduce water activity [7]. However, high temperatures and long drying periods typically reduce the quality of the final product. Avila and Silva [8] reported that several reactions affect the color during processing of fruits and their derivatives.

Lemon (*Citrus limon* L.) is a very important citrus species with a strong commercial value and generates a large amount of waste. Lemon peel accounts about 50-65% of the fruit

weight [9] after the extraction of the juice either by manual or mechanical methods. Few methods have been in use for the extraction of juice from fruits. Among all of them, only screw type juice extractor is employed to extract the juice from citrus [10]. That method consumes both time and energy besides the fact that its production is very low with high waste quantity of fresh fruits [11].

More recently, new methods of juice extraction such as juice processing from the whole and separated aril sacs have been explored [12]. These methods were reported to save energy and/or time intense; however, it may produce unhygienic juice with low quantity [13].

Researches have been published on the thermal processing of citrus juice and its shelf-life [14] however, the effects of different extraction methods on the quality, characteristics and components of citrus peels (lemon peel) are still limited. Therefore, this study was aimed to determine the influence of some different juice extraction methods (screw type hand operated juice extractor and pressed squeeze juice extractor) on the chemical properties of lemon peels drying by different drying methods (microwave, solar and oven drying).

II. MATERIALS AND METHODS

A. Materials

Fresh lemon (*C. Limon*) peel was prepared in Food Science and Technology Lab. (NRC).

B. Chemicals and Reagents

Chemicals and reagents (An analytical grade) were purchased from Sigma Chemical Co. (St. Louis, Mo, USA). The used water was distilled using water distillation apparatus HAILTON (Kent CT9 4JG).

C. Preparation of Lemon Peels

Lemon peels were washed with distilled water then the juice was extracted using two types of juice extraction methods: (1) screw type hand operated juice extractor, (2) pressed squeeze juice extractor. Fresh lemon peels were cut as cubes of 1 cm³ before processing.

D. Technological Treatments

1. Extraction of Juice

Fruits were inspected thoroughly for any damage and spoilage. Selected fruits were thoroughly washed in tap water to remove dirt, dust particles and insecticidal residues. Screw type hand operated juice extractor and power operated commercial juice extractor (squeeze) were used in the study. Fresh lemon peels were cut as cubes of 1 cm³ before

Azza A. Abou-Arab is with the Dept. of Food Tech., National Research Centre, 33 Bohouth St. Dokki, Giza, Egypt., P.O.Box12622 (Corresponding author; fax: (+202) 33370931; e-mail: drazza_nrc@yahoo.com).

Marwa H. Mahmoud and Ferial M. Abu-Salem are with the Dept. of Food Tech., National Research Centre, 33 Bohouth St. Dokki, Giza, Egypt., P.O.Box 12622 (e-mail: marwahanafy78@yahoo.com, ferial_mas@yahoo.com).

processing.

2. Drying

All lemon peels samples were dried using microwave, solar and air oven drying. The dried samples were milled to pass through 100 mesh screen sieves [2].

E. Chemical Analysis

Moisture, protein, ash, fat and fibers were determined in all lemon peel samples [15]. The tests were carried out in triplicate and the data were expressed as mean \pm SD.

1. Lignin Determination

Lignin content was determined gravimetrically [16] by using 70% (w/w H_2SO_4) solution to hydrolyze the cellulose and hemicellulose in 2 g (W1) of sample. After that, remaining suspension 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-weighed. The sample was dried at 105 °C for 24 hs and the weight was recorded (W2) and the residue was heated until all carbon was eliminated at a temperature reached 650 °C. After cooling, it was weighted (W3) and lignin content (%) was determined according to [16]:

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

where: W1 is weight of sample, W2 is sample after drying, W3 is weight of lignin.

2. Mineral Determination

Individual stock solution (1000 mg/L) of micro-elements, iron (Fe), copper (Cu), zinc (Zn), manganese (Mn), cadmium (Cd) and lead (Pb) as well as macro-elements like calcium (Ca), potassium (K), magnesium (Mg) sodium (Na), and phosphorus (P) were provided by Merck (Darmstadt, Germany). The sample solutions were subsequently measured for micro-elements [15] using PG-spectrophotometer atomic absorption 990 (PG Instruments Ltd.) using air-acetylene flame atomization, equipped with a 10-cm burner and a deuterium lamps for back ground correction. The maximum absorbance of each element was applied according to specific wavelength of cathode lamps.

The content of K, Ca, Na and Mg were determined using a flame photometer [17] while (P) content was determined using spectrophotometric method as outlined in the method of AOAC [15].

F. Statistical Analysis

All data were statistically analyzed by analysis of Variance (ANOVA) using the General Linear Model Procedure of the Statistical Analysis System. The significance of the differences among treatment groups was determined by Waller-Duncan k-ratio [18]. All statements of significance were based on probability of $P \leq 0.05$.

III. RESULTS AND DISCUSSION

Citrus is an important crop principally used in the food

industry for fresh juice production and peel is the main by-product during its processing. The chemical analysis of lemon peel byproduct was evaluated after different extraction (pressed squeeze and hand screw) and drying methods (solar drying, oven drying and microwave drying).

A. Effect of Juice Extraction and Drying Methods on the Moisture Content of Lemon Peel

Table I proved that there were significant differences ($P < 0.05$) between the percentages of moisture in the samples using different juice extraction methods. The highest value of moisture content was detected in lemon screw type hand operated fresh followed by lemon squeeze fresh which recorded 65.11 and 64.42% fw, respectively. These levels of moisture were decreased by drying methods. In hand operated screw, moisture content recorded 15.22, 14.05 and 13.16% fw, in oven air drier, microwave and solar methods, respectively whereas, the recorded values for lemon squeeze were 14.36, 13.51 and 12.64% fw, respectively. On the other hand, solar-drying had the less percentage of moisture followed by drying using a microwave, whereas air oven drying was ranked last (Table I).

The solar dried samples resulted in the lowest moisture content probably due to the shielding effect of the relative humidity in the air which prevents the radiation. [19].

B. Effect of Juice Extraction and Drying Methods on the Ash Content of Lemon Peel

Results in Table II reflect that there are significant differences ($P < 0.05$) between the different juice extraction methods, whereas, increased rates of these components decrease moisture contents of the samples and vice versa which led to false increased in other components.

The high ash content was detected in fresh lemon screw type hand followed by fresh lemon squeeze which recorded 2.03 and 1.69 % fw, respectively and were increased by the dryer methods. When screwed lemon type hand of was dried by microwave, solar or air oven method, the recorded ash contents were 6.11, 6.31 or 6.02% fw, respectively. However, these values were 5.80 5.41 and 5.06% fw, respectively in the lemon squeeze ash. These results are in agreement with those reported by [20] who found that the ash content of lemon peel was 5.26%. The variation in ash contents also depends on plant species, geographical origins, their technique of mineralization, yet as well as impact of food process by drying [21].

TABLE I
MOISTURE CONTENT OF LEMON PEEL AS AFFECTED BY SOME DIFFERENT JUICE EXTRACTION AND DRYING METHODS (% FW)

Juice extraction methods	Control	Microwave - drying	Solar-drying	Air oven-drying	L.S.D at 5%
Lemon screw type	65.11 ^a	14.05 ^c	13.16 ^d	15.22 ^b	2.19
hand operated	± 3.42	± 2.32	± 1.97	± 2.62	
Lemon squeeze	64.42 ^a	13.51 ^c	12.64 ^d	14.36 ^b	2.08
	± 2.21	± 1.24	± 1.11	± 1.24	

All values are means of triplicate determinations \pm standard deviation (SD).

Means within rows with different letters are significantly different ($P < 0.05$).

TABLE II
ASH CONTENT OF LEMON PEEL AS AFFECTED BY SOME DIFFERENT JUICE
EXTRACTION AND DRYING METHODS (% FW)

Juice extraction methods	Control	Microwave - drying	Solar-drying	Air oven-drying	L.S.D at 5%
Lemon screw type	2.03 ^d	6.11 ^b	6.31 ^a	6.02 ^c	0.04
hand operated	±0.04	±0.02	±0.03	±0.02	
Lemon squeeze	1.69 ^d	5.41 ^b	5.80 ^a	5.00 ^c	0.02
	±0.03	±0.02	±0.03	±0.02	

-All values are means of triplicate determinations ± standard deviation (SD).

- Means within rows with different letters are significantly different ($P < 0.05$).

C. Effect of Juice Extraction and Drying Methods on the Protein Content of Lemon Peel

Table III indicated that there are significant differences ($P < 0.05$) between the different juice extraction methods. The highest value of protein content was detected in lemon squeeze fresh followed by lemon screw type hand operated fresh that recorded 0.33 and 0.26% fw, respectively. These levels showed an increase by the drying methods. Furthermore, protein content recorded 1.34, 1.09 and 1.05% fw, respectively with dried by solar, microwave and air oven methods. With regard to the content of lemon squeeze, the protein contents were 1.37, 1.41 and 1.09% fw, when drying by air oven, microwave and solar methods, respectively compared to control sample.

D. Effect of Juice Extraction and Drying Methods on the Fat Content of Lemon Peel

Table IV indicated that significant differences ($P < 0.05$) were observed between treatments which reflect the effect of the methods of juice extraction or drying. Additionally, the highest fat content was found in the lemon squeeze fresh then fresh lemon screw type hand operated which recorded 0.35 and 0.22% fw, respectively. These levels were increased to dried methods. In hand operated type lemon screw, fat content recorded 3.12, 2.21 and 1.20% fw, respectively with dried by air oven, solar, and microwave methods. With link to the squeezed lemon, fat contents were 3.41, 1.81 and 0.98% fw with dried by air oven, solar and microwave methods, respectively comparing to control sample. Similarly, Hassan et al. [22] reported that oven drying decreases the lipid content.

E. Effect of Juice Extraction and Drying Methods of the Crude Fiber Content of Lemon Peel

The lipid extraction of crude fiber content of the dried samples was analyzed using the acid and alkali digestion. The results shown in Table V indicated a significant ($P < 0.05$) decrease of fiber content in the different extraction types of lemon peel juice under different drying methods (microwave, solar and air oven drying). These results also indicated a variable in the levels of crude fiber of different samples and different sources. The highest value of fiber content was detected in hand operated lemon screw type followed by lemon squeeze which recorded 14.95 and 13.09% fw, respectively. These levels decreased by drying methods. In hand operated type lemon screw, crude fiber content recorded 13.22, 12.02 and 11.18% fw with dried by microwave, solar and air oven methods, respectively. The crude fiber contents in

lemon squeeze recorded 12.29%, 11.46% and 10.73% fw, respectively.

The current results also revealed that the procedure of microwave drying showed high effect on crude fiber retention content for different extraction methods of juice of lemon peel when compared to solar or air oven methods. Additionally, the increasing of drying temperatures resulted in a reduction of crude fiber content. These may be resulted from the degradation of other fibers such as hemicelluloses or cellulose during process which in turn reduced the content of crude fiber in the dried sample [23].

F. Effect of Juice Extraction and Drying Methods of the Lignin Content of Lemon Peel

Data in Table VI proved the levels of lignin in lemon peel (screwed lemon type hand operated and squeezed lemon). Results indicated that lignin concentrations of different samples are quite variable among different types of the sample source.

TABLE III
PROTEIN CONTENT OF LEMON PEEL AS AFFECTED BY SOME DIFFERENT JUICE
EXTRACTION AND DRYING METHODS (% FW)

Juice extraction methods	Control	Microwave-drying	Solar-drying	Air oven-drying	L.S.D at 5%
Lemon screw type hand operated	0.26 ^c ±0.02	1.05 ^b ±0.26	1.34 ^a ±0.02	1.09 ^{ab} ±0.02	0.25
Lemon squeeze	0.33 ^d ±0.04	1.41 ^a ±0.03	1.09 ^c ±0.03	1.37 ^b ±0.02	0.02

All values are means of triplicate determinations ± standard deviation (SD).

Means within rows with different letters are significantly different ($P < 0.05$).

TABLE IV
FAT CONTENT OF LEMON PEEL AS AFFECTED BY SOME DIFFERENT JUICE
EXTRACTION AND DRYING METHODS (% FW)

Juice extraction methods	Control	Microwave-drying	Solar-drying	Air oven-drying	L.S.D at 5%
Lemon screw type hand operated	0.22 ^d ±0.02	1.20 ^c ±0.55	2.21 ^b ±0.26	3.12 ^a ±0.26	0.65
Lemon squeeze	0.35 ^d ±0.15	0.98 ^c ±0.22	1.81 ^b ±0.16	3.41 ^a ±0.22	0.36

All values are means of triplicate determinations ± standard deviation (SD).

Means within rows with different letters are significantly different ($P < 0.05$).

TABLE V
CRUDE FIBER CONTENT OF LEMON PEEL AS AFFECTED BY SOME DIFFERENT
JUICE EXTRACTION AND DRYING METHODS (% FW)

Juice extraction methods	Control	Microwave-drying	Solar-drying	Air oven-drying	L.S.D at 5%
Lemon screw type hand operated	14.95 ^a ±0.03	13.22 ^b ±0.03	12.02 ^c ±0.03	11.18 ^d ±0.02	1.82
Lemon squeeze	13.09 ^a ±0.02	12.29 ^b ±0.03	11.46 ^c ±0.03	10.73 ^d ±0.03	1.80

All values are means of triplicate determinations ± standard deviation (SD).

Means within rows with different letters are significantly different ($P < 0.05$).

The highest value of lignin was detected in lemon screw type hand operated followed by lemon squeeze, which

recorded 4.75 and 3.23% fw, respectively. The relatively low content of lignin about 3.23-5.75% fw in peel samples indicated the absence of secondary wall of citrus tissues [24].

Results revealed that the oven-drying method was associated significantly ($P < 0.05$) with the increment of lignin in both of screw type hand operated peel and lemon squeeze peel.

Solar-drying exposes the materials to ultra violet radiation, which react with peel constituents to reduce lignin [25].

In screwed lemon type hand operated, lignin content was recorded 7.16, 3.78 and 4.13% fw, dried by oven, solar and microwave drying methods, respectively compared with the control sample. The corresponding values of lemon squeeze was 6.59, 3.02 and 3.20% fw 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 lemon peel followed by microwave drying methods.

TABLE VI
LIGNIN CONTENT OF LEMON PEEL AS AFFECTED BY SOME DIFFERENT JUICE EXTRACTION AND DRYING METHODS (%FW)

Juice extraction methods	Control	Microwav e- drying	Solar-drying	Air oven-drying	L.S.D at 5%
Lemon screw type hand operated	4.75 ^b ±0.03	4.13 ^c ±0.03	3.78 ^d ±0.02	7.16 ^a ± 0.02	0.02
Lemon squeeze	3.23 ^b ±0.02	3.20 ^c ±0.02	3.02 ^d ±0.03	6.59 ^a ±0.03	0.02

-All values are means of triplicate determinations ± standard deviation (SD).

- Means within rows with different letters are significantly different ($P < 0.05$).

G. Mineral Content of Lemon Peel

Table VII shows that the screwed lemon type hand operated (*C. limon*) peels had the highest content of K (202.11 mg/100 g), Mg (184.15 mg/100 g), Na (153.24 mg/100 g), Ca (135.18 mg/100 g), and P (39.33 mg/100 g) compared with lemon squeeze. The differences between amounts of different component contents can be attributed to the variability between cultivars. The variation within the content of some minerals would be concerned with the citrus maturation stage. Fortunately, the results of the present study (Table VII) showed that the levels of Cd were detected in a low concentration in both of lemon squeeze and screw type hand operated (1.18 and 1.20 mg/100 g), respectively. Elements like Pb were also detected in a very low concentration of all of the analyzed lemon peels, which were (0.04 and 0.05 mg/100 g) in squeezed lemon and screwed lemon type hand operated, respectively. Whereas, elements like Mn were not detected in lemon squeezed and screw type hand operated when drying methods were used. This implies that the Cd and Pb elements were not accumulated within the plant. These results indicated that, citrus peel could be a function supplier of valuable nutrients which is needed for normal functioning as the body system. The utilization of those peels can enhance the conversion of waste to wealth. It will additionally contribute positively to solid waste management and cleaner environments.

H. Minerals Content of Screwed Lemon Peel Dried by Different Methods

The results in Table VIII proved the effect of juice extraction by screw type hand operated method on the mineral content of lemon peel. The results proved that the Ca content of the lemon peel was 137.93 mg/100 g which was increased significantly ($P < 0.05$) by drying with solar, compared with control. This indicated that solar-drying could improve Ca content of the lemon peel compared with control.

At the same trend, solar-drying had the highest significant ($P < 0.05$) Zn value (15.26 mg/100 g). K content of lemon peel was 196.24 mg/100 g which reduced significantly ($P < 0.05$) by drying with the solar-dryer as compared with control.

Data revealed that solar-dryer lemon peel reduced significantly ($P < 0.05$) the level of Na, Mg, P, Fe and Cu of screwed lemon type hand peel samples, while, Na content was 149.52 mg/100 g, Mg(178.73 mg/100 g, P 35.71 mg/100 g, Fe 5.34 mg/100 g), and Cu (0.93 mg/100 g compared with control. On the other hand, Mn, Cd, Pb were not detected in the lemon peel.

I. Mineral Content of Squeezed Lemon Peel Dried by Different Methods

Table IX proved the effect of juice extraction method (squeeze) on the mineral content of lemon peel. The results showed that the Ca content of the lemon squeeze was increased significantly ($P < 0.05$) by drying with the solar-dryer 135.63 mg/100 g compared with control. The solar-drying improved Ca content of the lemon peel, followed by oven-drying 134.34 mg/100 g in lemon squeeze compared with control.

The same trend was found with solar-drying which had the significantly highest ($P < 0.05$) Zn value (14.36 mg/100 g) in lemon peel. The results indicated that the processing methods had an advantage in improving Zn quality of lemon peels. The results presented in Table IX indicated that K content of squeezed lemon was reduced significantly ($P < 0.05$) by drying with the solar-dryer 194.54 mg/100 g compared with control.

The results of Table IX proved that the solar-drying significantly ($P < 0.05$) reduced the level of minerals of squeezed lemon peel such as, Na (147.50 mg/100 g), Mg (177.33 mg/100 g), P (33.71 mg/100 g), Fe (4.32 mg/100 g), and Cu (0.90 mg/100 g). However, Mn, Cd, Pb were not detected in all lemon peel treatments.

The K was the most abundant element presented in all treated samples in agreement with the reported results of [26], [27].

Topuz et al. [28] found that the K was the predominant element presented in the investigated citrus cultivars, with a range of 1011-1364 mg/kg.

TABLE VII
MINERAL CONTENT OF LEMON PEELS (MG/100 G DM)

Juice extraction methods	Ca	K	Na	Mg	P	Zn	Fe	Cu	Mn	M	Cd	Pb
Lemon screw type hand operated	135.18 ^a ±2.00	202.11 ^a ±2.06	153.24 ^a ±2.02	184.15 ^a ±2.01	39.33 ^a ±2.00	13.81 ^a ±2.00	8.65 ^a 1.03±	1.88 ^a ±0.02	ND	ND	1.20 ^a ±0.02	0.05 ^a ±0.01
Lemon squeeze	134.25 ^b ±2.00	200.15 ^b ±2.02	152.31 ^b ±2.00	182.42 ^b ±2.01	38.22 ^b ±2.06	12.62 ^b ±0.02	7.38 ^b ±0.02	1.18 ^b ±0.02	ND	ND	1.18 ^b ±0.02	0.04 ^b ±0.01
L.S.D at 5%	2.80	3.73	3.34	3.36	3.37	0.92	2.94	1.83	-	-	1.30	0.71

- All values are means of triplicate determinations ± standard deviation (SD)

- Means within columns with different letters are significantly different (P < 0.05)

- ND: not detected.

TABLE VIII
MINERAL CONTENT OF LEMON PEEL SCREW TYPE HAND OPERATED (*C. LIMON*) DRIED BY DIFFERENT METHODS (MG/100G DM)

Sample types	Ca	K	Na	Mg	P	Zn	Fe	Cu	Mn	Cd	Pb
Control	135.18±2.03	202.11±3.0	153.24±3.0	184.15±3.0	39.33±2.0	13.81 ^d ±0.02	8.65 ^a ±0.02	1.88 ^a ±0.02	ND	1.20	0.05
Microwave- drying	133.78 ^d ±3.0	199.34 ^b ±3.0	151.38 ^b ±2.03	181.15 ^b ±2.19	37.51 ^b ±2.08	13.99 ^c ±0.03	7.01 ^b ±0.02	1.08 ^b ±0.02	ND	ND	ND
Solar-drying	137.93 ^a ±3.15	196.24 ^d ±2.0	149.52 ^d ±3.0	178.37 ^d ±2.0	35.71 ^d ±2.0	15.26 ^a ±0.02	5.34 ^d ±0.02	0.93 ^c ±0.02	ND	ND	ND
Air oven-drying	136.24 ^b ±2.38	198.17 ^c ±2.52	150.37 ^c ±2.52	180.30 ^c ±3.0	36.22 ^c ±1.53	14.17 ^b ±0.02	6.76 ^c ±0.02	0.95 ^c ±0.02	ND	ND	ND
L.S.D at 5%	2.55	2.18	2.32	2.10	1.11	0.03	0.02	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: not detected.

TABLE IX
MINERALS CONTENT OF LEMON PEEL SQUEEZE (*C. LIMON*) DRIED BY DIFFERENT METHODS (MG/100G DM)

Sample types	Ca	K	Na	Mg	P	Zn	Fe	Cu	Mn	Cd	Pb
Control	133.25±2.02	200.15±3.0	152.31±2.18	182.42±2.42	38.22±1.05	12.62±0.03	7.38±0.02	1.18±0.02	ND	1.18	0.04
Microwave- drying	132.23±2.13	196.54±2.0	151.17±1.55	180.18±2.06	36.61±2.18	13.17±0.02	6.91±0.03	1.02±0.02	ND	ND	ND
Solar-drying	135.63±2.37	194.54 ^d ±2.32	147.50 ^d ±2.53	177.33 ^d ±2.02	33.71 ^d ±1.32	14.36 ^a ±0.02	4.32 ^d ±0.02	0.90 ^d ±0.02	ND	ND	ND
Air oven- drying	134.34±2.15	196.37 ^c ±2.10	149.17 ^c ±2.30	179.31 ^c ±2.33	34.28 ^c ±1.22	13.52 ^b ±0.03	5.77 ^c ±0.03	0.93 ^c ±0.02	ND	ND	ND
L.S.D at 5%	2.35	2.10	2.29	2.02	1.09	0.03	0.02	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: not detected.

IV. CONCLUSION

The variation in the results of chemical and mineral composition of lemon peels extracts by two extraction methods was recorded. Juice extracted with screw type juice extractor maintained better qualitative characteristics like mineral content, crude fiber and lignin. Microwave drying method had the highest content of crude fiber and mineral however, solar drying method had the highest content of ash and protein compared to air oven drying method which had the highest content of both of fat and lignin. It could be concluded that extraction of juice by screw type and microwave drying method were the best processing methods for lemon peel as a preparative step as food additives.

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