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Evaluation the bioactive compounds extracted from dried banana (Musa sp.) peels which obtained by different drying methods

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ABSTRACT

The good utilization of banana peel as a cheaper source of bioactive compounds largely depends on the favorable temperature and relative humidity of the drying kinetics.

The present study investigated the effect of five known drying methods on the biological activity of banana peel to identify the suitable drying conditions giving dried peel has good physical properties, minimum loss of bioactive compounds and antioxidant properties. The results showed that microwave irradiation at the power level of 950 W for 6 min was the most suitable condition, as these dried peels had the highest antioxidants recovery and antimicrobial activity. This was followed by vacuum over drying at 65°C (8h), hot air over drying at 110°C (4h), and then dry air oven drying at 60°C (12h 30 min), and at last sun drying. Samples of peels dried by microwave possessed a total phenolic content of 26.88 mg (GAE/g DM), total flavonoids content of 31.81mg (QE/g DM), total monomeric anthocyanins of 5.34mg (CE/g DM) and total tannins content of 22.00mg (TE/g DM). Also possessed highest antioxidant activity at four concentration of 80% methanol extract of banana peel (0.5, 1.0, 1.5 and 2.0 mg/ml) to scavenge free radical of DPPH in comparison to ascorbic acid. The inhibitory percentages were 15.40, 24.46, 44.95, and 65.22 mg/ml respectively.

Results revealed that 80% methanol extract of microwave method had the strongly effect than the other drying methods, which inhibited species at 450 mg/ml against bacteria including. *E coli*, *S.aureus* and *B. subtilis*, yeast including *C. albicans* and fungus including *A. niger*. The inhibition zones diameters at concentration 450mg/ml from methanolic banana peels extract were 1.55, 6.88, 8.35, 0.95 and 8.74 cm respectively.

These results clearly encourage the application the waste part of banana peel as an important natural source of bioactive compounds whereas the good utilization largely depends on the favorable drying condition beside the favorable solvent before it can be used.

Key words: Antioxidant; Antimicrobial; banana peel; bioactive compounds; drying conditions

Introduction

Banana (Musa Sp.) is the second largest producer after citrus fruit account for only around 16% of global world products and it is an abundant fruit in Asian and African countries (Gonzalez-Montelongo *et al.,* 2010)

The main by-product of the banana processing industry is the peel, accounting for 35-38% of the total fresh mass of ripe fruit, and there is not further involved in remarkable industrial applications. This by-product constitutes an environmental problem because it contains large quantities of nitrogen and phosphorus and its high water content makes it susceptible to modification by microorganisms (El-Zawawy, 2015) these peels were not being used for any other purposes and are mostly dumped as solid waste at large expense.

It is known by its local and traditional use to promote wound healing mainly from burns and to help overcome or prevent a substantial number of illnesses, as depression (Aboul-Enein *et al.,* 2016; Navneet *et al.,* 2017)

Generally, peels from consumed bananas are used in the animal feeding, as organic fertilizer or they are simply discarded.

Currently, there are few reports in literature describing the usage of this non-edible portion (peel), e.g., production of methanol and ethanol (Gunaseelan, 2004).

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Depending on the technology employed, the disposal of these peels (pomac) can be converted into commercial products either as raw materials for secondary processes such as ingredients of new products with therapeutic activity. These natural products can also be used directly as functional compounds in human nutrition, and they are interesting sources of bioactive secondary metabolites, however, potentiality of banana peel utilization largely depends on the favorable drying condition of the materials before it can be used for further processing (scariett and Vuong 2017).

Recent studies provided useful information on the chemical composition of banana peel, which are essential of the understanding of their nutraceutical potential in the food industry. This investigation was undertaken to evaluate the antioxidant activity of banana fruit peel with the aim of exploiting the potential value of the waste banana peels and the role of these antioxidant (Aboul-Enein *et al.,* 2016).

The chemical composition of banana's peel comprises mostly carotenoids, phenolic compounds, and biogenic amines. The biological potential of those biomasses is directly related to their chemical composition, particularly as pro-vitamin. A supplementation as potential antioxidant, attributed to their high phenolic constituents (flavonoids). Therefore, banana's peel can be used as natural sources of antioxidants and could be of interest as raw material riches in beneficial bioactive compounds (Pereira and Marschin, 2015; Youryoun and Supapvanish, 2017) who found that the majority of banana peel exhibited 4 fold higher antioxidant activity the pulp. Edible pulp contain about 25% phenolic compounds of that present in the peel.

Gonzalez- Montelongo *et al.* (2010) studied the extraction conditions and its relation with bioactive compounds. The results revealed that acetone: water extracts were considerably more effective compared with methanol and ethanol at inhibiting the peroxidation of lipids in the B-carotene linoleic acid system or scavenging free radicals. In addition acetone: water most efficiently extracted all extractable components (54%).

Shanthy *et al.* (2011) studied the effect of ripening and solvent polarity on the content of bioactive compounds of crude banana peel and the protective effect of peel extracts of unripe, ripe and leaky ripe banana fruit on hydrogen peroxide- induced hemolysis and their antioxidant capacity. They treated the banana peel samples with 70% acetone, which were partitioned in order of polarity with water, ethyl acetate, chloroform ($CHCL_3$), and hexane sequentially. The findings of this investigation suggest the unripe banana peel sample had higher antioxidant potency than ripe and leaky ripe. Further on fractionation, ethyl acetate displayed high antioxidant activity than $CHCL_3$ and hexane fraction, respectively.

In contrast to the previous studies, Niamah (2014) revealed that methanolic extract of dry banana peels contain the highest the total phenolic and flavonoids concentration than ethanol , acetone and ethyl acetate extracts.

According to Gonzalez-Montelongo *et al.* (2010) fruit peels were superior to pulps in its amounts of health promoting constituents. Total amount of phenolic compounds in banana (Musa acuminate) peel ranged from 0.90 to 3.0 g/100 g dry weight.

Research is being focused on banana peel which was a rich and inexpensive source of antioxidant compounds and in most cases the fruit processing units can be successfully used as a source of phytochemical, and antioxidants. Since, 2014, there are few studies evaluate the presence of antibacterial activity and minimum inhibitory concentration of banana peel extracts on bacteria, mold and yeast. But, against periodontal pathogens as well as its functional properties has not yet been analyzed.

Naimah (2014) preformed her study on the antibacterial activity of banana peel, who demonstrated that 300 mg/ml concentration from methanolic banana peel extract had broad inhibitory spectrum against gram positive and negative bacteria, yeast and molds.

El- Zawawy (2015) found that maximum extracts showing the antibacterial activity range from 1 to 8.5 cm and maximum extracts showing an antifungal activity range from 2.5 to 8.5 cm from ethanolic peel extracts. The obtained results suggest that banana peel extract has the best antifungal activity and moderate inhibition on *Salmonella typhi*, *Salmonella paratyphi, Bacillus subtiles* and very less against *Escherichia coli* Thus provide the scientific basis for the traditional uses of the studied peels in the treatment of fungal bacterial infections.

Drying is an important step to prepare starting material for further processing as it is associated with production cost and material quality. The drying process can lead to the degradation of bioactive compounds (Nguyen *et al.,* 2015).

Nindo *et al.* (2003) studied the effects of dry technologies for retention of physical quality and antioxidants in asparagus. Their results confirmed that hot-air drying method release the bound bioactive compounds to results in high recovery yield.

Wojdylo *et al.* (2009) studied the effects of vacuum microwave drying method for retention of bioactive compounds in strawberry fruits such as carotenoids, quercetin derivatives, phenolic acids and saponins and antioxidant capacity. Their results confirmed that microwave method possessed yields higher than the other drying application from these bioactive compounds.

Hamrouni-Sellami, *et al.* (2012) declared that each drying technique may be suitable for one starting materials but might not be for other materials. For example, microwave irradiation increased total phenolics recovery in sage (*Salvia officinalis* L.) plant, but it decreased phenolics recovery in strawberry fruit. Ambient air-drying was found to increase phenolics recovery in oregano and pepper mint leaves, but not in lemon balm.

In recent years, different drying techniques have been developed for drying plant materials for various downstream applications. They are either used separately (freeze drying, heat pump dehumidified air, vacuum, hot air, sun).

Scariett and Vuong (2017) showed that different drying conditions significantly affected the physical, chemical, and antioxidant properties of dried banana peels. Peels dried by microwave or freeze–drying had good physical properties, minimum loss of bioactive compounds, and antioxidant properties.

Therefore, there is a lack of more information on drying conditions for the preparation of dried banana peels as a starting material for further utilization.

The aim of this study is (i) attempt to identify the best drying method and conditions which possess an insignificant effect on the physical, chemical and antioxidant properties of dried banana peels. (ii) To highlight the bioactive compounds contents in dried banana (Musa sp.) peels and determine in vitro antioxidant activities and their potential as bacterial and fungal inhibitors.

Materials and Methods:

Chemicals:

All chemicals were obtained from Scharlab S.L, Spain. Standard of phenolic acid (Gallic acid), of flavonoids (Quercetin), of monomeric anthocyanin (Cyanidin 3.Glucoside) and of tannins (Folin-Ciocalteu's reagent), and Diphenyl picryl hydrazyl (DPPH) were obtained from sigma-Aldrich Chemicals Co.uk. All chemicals and reagents used were of analytical grade.

Microbial Strains:

Bacterial cultures of *Escherichia coli*, *staphylococcus aureus*, and *Bacillus subtilis*, yeast cultures of *Candida albicans* and fungal cultures of *Aspergillus niger* were obtained from the laboratory of Microbiology, Botany Dep. Faculty of Science, Mansoura Uni. The strains were maintained on agar slants at 4°c and activated at 37°c for 24h on nutrient agar (NA) for bacteria and on potato dextrose agar (PDA) for yeast, while fungi were activated at 29°c for 4 days on PDA media before any susceptibility test.

Experimental design for drying banana peels:

Yellow bananas (Musa sp.) were purchased from a local market, Giza, Egypt. Fresh peels were manually separated from the pulp, cut longitudinally with 2 cm width and blanched at 95°C for 5 min to inactivate endogenous enzymes before drying. Fresh peels were randomly placed on a tray in a single layer and mixed occasionally during drying. Fresh banana peels were dried to a constant weight using five drying methods including:

Microwave drying (MD):

Sample was placed in a single layer on the plate of microwave oven (Panasonic, model 551. Italy). The system was set up at three levels of power at 130.650 and 950W .Irradiation was set up for 5s on; followed by 5s off to prevent overheating and burning. Mass check was done every 2 min at first, followed by every 30s and every 10s.Irradiation was continued until the sample weight remained unhanged. Total irradiation time was recorded for each power level.

Vacuum drying: (VD)

Sample was placed in an aluminum tray and then dried under two temperature levels 65 and 100°c with a vacuum pressure of 67 KPa using a vacuum oven (Thermolins, Marrickville, NSW, Australia). The samples were dried until constant weight is obtained. Drying time for each temperature was recorded. Samples were weighed every 2h at first, followed by every 1h and every 30min using a digital balance with error 0.001g.

Humidity free air-drying: (DD)

Peels were put in an aluminum tray and then dried at three different temperatures (30, 45 and 60°C) with low relative humidity (16 to 20%) using dehumidifier (MK2-75, Caloundra, QLD, and Australia). Samples were dried until constant weight and the drying time for each temperature were recorded. Also samples were weight every 2h at first, followed by every 1 hr and every 30min.

Hot air-drying: (HD)

Peels were placed in an aluminum tray and dried under two temperatures (70°C and 110°C) with maximum air circulation to constant weight using an oven drier (Equipment Pty Lid., EW, Germany) .

Sun drying: (SD)

Sample was placed in a single layer on a carton tray and dried under the sun from 9 AM to 5 PM until constant weight is obtained. Air temperature was recorded and ranged from 30 to 38°C.
Dried peels were then ground using a commercial blender (Duisburg-Germany, model WI). Dried ground peels were kept in a sealed polyethylene bags and stored at – 18°c and used as feedstock for experiments in this study.

Determination of physical properties of dried banana peels:

Recovery yield (%), moisture content (M %) water activity (wa) and extractable solid content (Ex %) are important parameters for the determination of a suitable drying method. Recovery yield was defined as the amount of dried peel obtained from fresh peel expressed in percentage (%). Moisture content (%) of the dried ground peel was determined by measuring the weight difference before and after drying for 15 h at 110°C using a hot air oven (LABEC, PSW, Germany). Water activity was measured using a water activity meter (Hygrometer model 4TE. Washington, USA), extractable solid content (%) was determined by drying 100 ml. of the extract at 80°c under reduced pressure for 24h using a vacuum oven (Model 5803, Pullman, Washington, USA), as described by Nguyen *et al.* (2016).

Quantification of bioactive compounds in dried banana peels:

Preparation of extracts:

8 gram from dried banana peel samples transferred to flask and added to 100ml of the solvent (80% methanol) and then stored at 25°c. After 24h, infusions were filtered through Whatman.6 filter paper and residue was re-extracted with equal volume of the solvent. After 48h, the process was repeated. Combined supernatants were evaporated to dryness under vacuum at 40°c using rotary

evaporator. The obtained extracts were kept in sterile sample tubes and stored in a refrigerator at 4°c (Stankovi, 2010).

Bioactive compounds determination:

Polyphenols content:

Extractable polyphenols content (TPC) of banana peel extracts were spectrophotometrically determined by Folin Ciocalteu's reagent assay using Gallic acid as standard according to Vuong *et al.* (2015). The sample (0.1ml) of the former extract was mixed with 0.5 ml of Folin-Ciocalteu's reagent and swirled. After 3 min, 1.5 ml of sodium carbonate solution (7%) was added and mixed, and then it was completed to 10ml. with distilled water. The absorbance was determined at 750 nm using spectrophotometer (Unicum UV 300). The total polyphenols in the samples was expressed as mg Gallic Acid Equivalents (mg GAE/G dry weight), using a calibration curve. All samples were analyzed in triplicates.

Total flavonoid content:

Total Flavonoids (TFC) of banana extracts were spectrophotometrically determined by the aluminum chloride method using quercetin as standard (Vuong *et al.,* 2015). The absorbance was measured against blank at 510 nm by using spectrophotometer. Total flavonoids in samples were expressed as mg Quercetin Equivalents (QE/g dry weight). All samples were analyzed in triplicates.

Monomeric anthocyanins :

The Total Monomeric Anthocyanin Content (TAC) of banana peel extracts were measured using a spectrophotometric $_{P}$H differential protocol (Lee *et al.,* 2005). The extracts were mixed thoroughly with 0.025M potassium chloride PH 1.0 buffer in 1:36 ratio of extract to buffer and the absorbance of the mixture was measured at 510 and 700 nm after 15 min. The extracts were combined with 0.4M sodium acetate buffer $_{P}$H 4.5 and the absorbance of this solution was measured at the same wave lengths. The absorbance of this solution was measured at the same wave lengths. The TA in the extract was calculated as follows:

$$TA = ((A510\text{-}A700))\ _{P}H\ 1.0\text{-}\ (A510\text{-}A700)_{PH4.5} \times MW \times (1000/W \times Y)$$

Where A is absorbance, MW is moleculer weight for cyanidin 3- glucoside (449.2 g/ mol), W is the molar extinction coefficient of cyaniding 3- glucoside (26.9001/mol cm^{-1}) and Y is path-length (cm), and expressed as mg of cyanidin 3- glucoside equivalents (CE)/g dry weight.

Total tannins content:

Total tannins (TTC) of banana peel extracts were measured using the Folin-Ciocalteu reagent according to Chanwitheesuk *et al.,* (2005) Absorbance was measured against prepared reagent blank at 760 nm by using spectrophotometer. Total tannins in sample were expressed as mg tannic acid equivalent (TE)/g dry weight sample (mg TE/g DM).

All samples were analyzed in triplicates, using a tannic acid solution as a standard solution.

Antioxidant activity:

Inhibiting action of dry matter of banana peel against stable free radical diphenyl picryl hydrazl (DPPH) was determined by the method of Singh *et al.* (2015). Different dilutions of the extracts were prepared 0.5, 1.0, 1.5 and 2.0 mg/ml and added to 2ml of DPPH (5.9mg/100ml methanol). Absorbance was measured at 517 nm against control (ascorbic acid) using a spectrophotometer (Hitachi). The capacity to scavenge the DPPH radical was calculated using the following formula:

% Inhibition =] (Ao-A)/Ao) x 100]where Ao is the absorbance of DPPH without sample (control) at 517 nm; A is the absorbance of test sample and DPPH (A calibration curve was constructed by plotting

percentage inhibition against concentration of trolox and the antioxidant capacity of the samples was expressed as mg (trolox equivalents)/g.

Determination of antibacterial activities:

Inhibitory for bacteria and yeast test:

Inhibitory for bacteria and yeast growth were assayed according to Murray et al. (2007) using well agar diffusion method. Candida and all bacteria were suspended in sterile water and diluted to 10^6 CFU/ml. 0.1 ml were Trans to PDA and ND media respectively. Three wells (6mm) worked in agar and 0.2 ml from methanolic banana peels extract were concentration (250,350,450) mg/ml. After 48h for incubation, the diameter of inhibition zones was measured by holding the measuring device.

Inhibitory for mold test:

Inhibition of mycelial growth was assayed according to Nene and Thapliyal(1993). The autoclaved medium was maintained in a water batch at 45°c. 1.0 ml from methanolic banana peels extract were concentration (250.350.450) mg/ml were delivered into the wells. Added to PDA. (12ml was poured in each Petri dishes) .A 6 mm disc from mycelium of old culture of molds transferred to the center of Petri plate. Three replicate Petri plates were used per treatment. The control samples were used plates containing mycelium disc without methanolic. All plates were incubated at 25°c for 3-5 days. After molds growth was calculated as colony diameter against negative controls was measured in terms of percent mycelia inhibition by the formula:
Growth inhibition (%) = (Dc-Dt/Dc) x 100
Where Dc is diameter of control, Dt is diameter of treatment.

Statistical analysis:

Each drying condition was performed in triplicate, and mean value and standard deviation were calculated. Comparisons were performed by analysis of variance (ANOVA). Statistical analyses were run using SAS software.

Results and Discussion:

Effect of different drying methods and conditions on physicochemical and antioxidant properties of banana peel:

Microwave has been widely used for the dehydration due to its advantages such as a short drying time and low energy consumption; however, this method has some drawbacks such as charring, degradation of bioactive compounds, and uneven heat distribution, Therefore, this study determined the impact of three different microwave powers ranging from 130 to 950W on the physicochemical and antioxidant properties of banana peels.

Table (1) shows that the higher the microwave power applied the shorter time was required for drying banana peels to constant weight. Results revealed that different microwave drying conditions did not significantly affect the recovery yields of dried peels from the fresh peels. Approximately 12% of the fried peels could be obtained from fresh peels after dehydration. All dried samples were found to have low moisture content (13.8-14.7%) and low water activity (0.38-0.43). Extractable solids are related to the recovery yield of crude extract from the dried samples after extraction; therefore, microwave drying conditions did not significantly affect the extractable solids. Approximately 22-26gm of crude extract could be obtained from 100 gm of dried peels under the extraction conditions and sample to solvent (80%methanol) ratio of 8g/100ml.

Also, different microwave drying conditions did not significantly affect TPC in peels; however, they did affect the levels of TFC, TAC and TTC. The peels irradiated at 950 W for 6 min or 650 W for 7 min were found to have the highest levels of TFC, TTC, and TAC respectively. In contrast to our findings Nguyen *et al.* (2015) reported that the phenolic content of dried phyllanthus amarus increased

as the microwave power increased from low (200 W) to medium (400 W), and then decreased at high power (600W), however, no significant changes were observed in flavonoids and anthocyanins. The differences might be explained by the stability of phenolic compounds, which vary according to genetic diversity of the tested samples. Our finding revealed that the higher the concentration of banana peel extract tested the stronger antioxidant activity could be obtained (Table 6 and fig1), also, results showed that the higher the microwave power applied, the samples possessed highest antioxidant activity (950 W for 6 min) whereas, the samples dried at lower power possessed the lowest activity (130W for 9min), but not significantly different from 650 W /7 min and 950W/6min was observed (Table 6 and Fig1.). Based on the former results, irradiation at 950 W for 6 min was deemed the ideal microwave dry condition for banana peels, and these conditions were used in comparison with other drying methods.

Table 1: Effect of microwave drying on physical properties and bioactive compounds of dried banana peels:

Levels of power (W)	Recovery yield (%)	Physical parameters			Bioactive compounds (Dry basis)			
		M (%)	Ex (%)	Wa	TPC (mg GAE/g)	TFC (mg QE/g)	TAC (mg CE/g)	TTC (mg TE/g)
130	12.11	13.8±0.09	21.8±0.06	0.38±0.00	26.06±0.05	24.00±0.01	3.53±0.01	16.87±0.02
650	12.30	14.3±0.06	23.4±0.05	0.40±0.00	26.39±0.02	29.75±0.03	4.22±0.04	21.60±0.01
950	12.42	14.7±0.07	26.2±0.01	0.43±0.00	26.88±0.03	31.81±0.02	5.34±0.02	22.00±0.02

M: moisture (%); EX : Extractable solid (%); Wa: Water activity .
The values are the mean ± standard deviation for at least triplicate experiments and P value is statistically highly significant at the 0.001 levels

The second drying method was used, the vacuum drying conditions. The application of vacuum has advantages such as decreasing of drying time and lowering the temperature. In this study two drying conditions were used for the dehydration of banana peels; vacuum pressure of 67 KPa with 65°C and vacuum pressure of 67 KPa with 100°C. Table (2) reveals that the higher the drying temperatures, the shorter the drying time required for the dehydration of banana peels to constant weight. Results indicated that the two different drying temperatures did not significantly affect recovery yields of dried peels from fresh peels or total extractable solids, approximately 11.5 and 21.0% respectively; however, these conditions significantly affected moisture content and water activity (Table 2). Dried peel obtained from high temperature, and short time (100°C 5h) had higher moisture residue (11.5%) and higher water activity (0.29). It is likely that fast evaporation at very high temperature has quickly dried the outer layers of the material and Blocked water channels in the sample and prevent the water diffusion from inside to the sample surface, resulting the high residue moisture of the final sample Garau *et al.,* 2007) These results were in agreement with that of Scariett and Vuong (2017). Who demonstrated that a higher moisture residue was found in sample obtained from a higher drying temperature, however, the differences were not statistically significant.

In contrast , the results revealed that bioactive of banana peel was highly affected by the drying temperature at the same vacuum pressure (67 KPa) , the higher the drying temperature applied, the lower the values of total bioactive compounds were observed, indicating that temperature significantly affected the retention of phenolic compounds.

Table 2: Effect of vacuum drying on physical properties and bioactive compounds of dried banana peels:

Levels of temperature (°C)	Recovery yield (%)	Physical parameters			Bioactive compounds (Dry basis)			
		M (%)	Ex (%)	Wa	TPC (mgGAE/g)	TFC (mg QE/g)	TAC (mg CE/g)	TTC (mg TE/g)
65	11.46	8.4±0.07	20.9±0.05	0.23±0.00	18.20±0.03	20.08±0.02	6.91±0.01	15.70±0.02
100	11.5	11.5±0.08	21.2±0.03	0.29±0.00	13.11±0.06	8.62±0.01	2.28±0.03	5.25±0.04

M: moisture (%) ; EX : Extractable solid (%); Wa: Water activity .
The values are the mean ± standard deviation for at least triplicate experiments and P value is statistically highly significant at the 0.001 levels

When increasing drying temperature from 65 to 100°C, an important proportion of bioactive compounds were last, accounting for approximately 28 % of total phenolic compounds and approximately 67 % of flavonoids, anthocyanins and tannins. Similarly, higher antioxidant activity was

observed by increasing the concentration of banana peel extract tested for each temperature. These findings indicated that drying at low temperature of 65°C with vacuum pressure of 67 KPa was the most suitable condition than 100°C, and this condition was used to compare with other drying techniques. Drying at temperatures above 65°C is unfavorable due to the possibility of inducing oxidative condensation or decompositions of thermo labile compounds. Heat treatment at high temperature might release bound phenolic compounds but might also decompose those phenolics which are heat unstable. Moreover, under vacuum pressure, the boiling point of water is reduced, thus reducing the operating temperature. However, the absence of a drying medium in the vacuum drying chamber disables convective heat transfer, which slow down the drying rate (Mueller – Harvey, 2001)

The third drying method was used; the hot – air drying. Hot air oven drying is a common drying technique for the dehydration of foods as it is easy to set up with low initial investment; however this method can affect the quality of samples depending on the temperature applied.

In the current study, two temperatures were tested for the dehydration of banana peels (70°C and 110°C). Table (3) shows that the higher the drying temperature , the shorter the time required for the banana peel to reach constant weight and the high temperature significantly affected physical , chemical and antioxidant properties of banana peels . Lower recovery yield, moisture content, and water activity were observed in the peels dried at 110°c when compared to the peels dried at 70°C, however, the two different tested temperatures did not significantly affect the extractable solids of dried peels

Table (3) also revealed that the drying temperature significantly affected the content of bioactive compounds of the dried peel. In contrast, the dried peels obtained at 110°C had the highest TPC (16.22 mg GAE/gDM) TFC (12.97mg/QE/gDM), TAC (3.09mgCE/gDM) and TTC (14.37TE/gDM). In comparison with drying at 70°c , the peels dried at 110°c had three times higher levels of TPC and TTC ,two times higher levels of TFC and ten times higher levels of TAC , indicating that the higher drying temperature in the presence of oxygen within a short time could retain higher levels of all bioactive compounds . Similarly, higher antioxidant activity was observed by increasing the concentration of banana peel extract tested for each temperature and the peels dried at 110°C had significantly greater antioxidant activity than that of the peels dried at 70°C (Table 6 and fig 1). This behavior could be related to long time exposing to heat when dried at low temperature, which may promote a decreased antioxidant capacity (Garau *et al.,* 2007). Moreover, derived products from Millard reaction, which can be generated and accumulated at high temperature, might have an effect on antioxidant activity of the final product. Therefore, hot air-drying at 110°C was the best drying condition and used to compare against other drying methods.

Table 3: Effect of hot air-drying on physical properties and bioactive compounds of dried banana peels

Levels of temperature (°C)	Recovery yield (%)	Physical parameters			Bioactive compounds (Dry basis)			
		M (%)	Ex (%)	Wa	TPC (mgGAE/g)	TFC (mg QE/g)	TAC (mg CE/g)	TTC (mg TE/g)
70	11.0	7.5	17.8±0.04	0.23±0.00	5.40±0.01	6.18±0.01	0.31±0.02	4.78±0.06
110	9.5	5.8	17.3±0.09	0.18±0.00	16.22±0.03	12.97±0.02	3.09±0.08	14.37±0.01

M: moisture (%) ; EX : Extractable solid (%); Wa: water activity .
The values are the mean ± standard deviation for at least triplicate experiments and P value is statistically highly significant at the 0.001 levels

Effect of modification of relative humidity and temperature on drying kinetics was the fourth method of drying was studied. This method was found to have advantages such as improved retention of aroma and color in comparison with the hot air-oven drying method. In this study three temperatures (30, 45, and 60°C) were used. Relative humidity was recorded from 16 to 20%. The results (Table 4) indicated that the higher temperature applied the shorter the drying time required obtaining the constant weight of dried sample. The different conditions were revealed not to significantly affect the recovery yields of dried peels; however they slightly affected other physical properties of dried peels such as moisture content, water activity and extractable solids (Table 4). Dehumidified drying at higher temperature (60°C) gave a lower moisture content, lower water activity, and higher extractable solids

Also, results indicate that different dehumidifier drying conditions significantly affected levels of bioactive compounds and consequently antioxidant properties of banana peels. Dried peels at 60°C contained more bioactive compounds than peel dried at other temperatures .The level of TPC and TTC at 60°C was 25% higher than those in samples dried at 30°c. Similarly, the level of TFC and TAC of

the samples dried at 60°C was about 50% higher than that of the samples dried at 30°C. In the case of antioxidant activity of dried peels at 60°C (for 13 h) also had the highest antioxidant activity and increased by increasing the concentration of banana peel extract tested (Table 6 & Fig.1) . These findings indicated that dehumidifier drying at 60 °C for 13 h (high temperature, short time) was the best among the investigated temperatures, and these conditions were used to compare with other drying techniques .These results were in agreement with the study of Erbay and Icier (2009) whereby olive leaves were dried with low relative humidity air under different temperatures (45-55 °C). They reported that temperature in the range of 50.5-53°C and short processing time minimized total phenolic loss as well as total antioxidant activity loss. The loss might be attributed to the longer time of exposure to heat and oxygen encountered when lower temperatures were applied.

Table 4: Effect of humidity free air-drying on physical properties and bioactive compounds of dried banana peels

Levels of temperature (°C)	Recovery yield (%)	Physical parameters			Bioactive compounds (Dry basis)			
		M (%)	Ex (%)	Wa	TPC (mg GAE/g)	TFC (mg QE/g)	TAC (mgCE/g)	TTC (mg TE/g)
30	10.0	12.8±0.07	27.1±0.08	0.36±0.00	8.62±0.03	9.45±0.04	3.10±0.02	10.29±0.06
45	10.1	11.2±0.08	28.6±0.04	0.33±0.01	9.22±0.02	14.35±0.02	3.77±0.01	11.00±0.07
60	10.4	10.4±0.07	29.9±0.01	0.30±0.07	10.87±0.06	18.90±0.03	4.42±0.02	12.83±0.05

M: moisture (%) ; EX : Extractable solid (%); Wa: water activity .
The values are the mean ± standard deviation for at least triplicate experiments and P value is statistically highly significant at the 0.001 levels

Table 5: Effect of sun drying on physical properties and bioactive compounds of dried banana peels

Levels of temperature (°C)	Recovery yield (%)	Physical parameters			Bioactive compounds (Dry basis)			
		M (%)	Ex (%)	Wa	TPC (mgGAE/g)	TFC (mgQE/g)	TAC (mg CE/g)	TTC (mg TE/g)
30-38	12.7	6.9±0.02	31.75±0.06	0.20±00.0	7.80±0.01	9.96±0.08	1.94±0.02	4.56±0.06

M: moisture (%) ; EX : Extractable solid (%); Wa: water activity .
The values are the mean ± standard deviation for at least triplicate experiments and P value is statistically highly significant at the 0.001 levels

The last drying method was studied; the sun drying. Although sun drying is the cheapest method, it was found to be not suitable method for dehydration of banana peels as a large loss of bioactive compounds were lost (Table 5). Only the sun drying had significantly higher extractable solids than those of the peels dried by the other methods (31.75%) whereas, the most of the bioactive compounds significantly changed and the peels possessed the lowest antioxidant activity (Table 6 & Fig. 1).

The differences between the present results in total phenolics, flavonoids, and tannins contents and other investigators may be attributed to plant species, environmental condition and sample preparation beside the type of solvent.

A comparison was done between the best condition of each drying method of banana peels on antioxidant recovery against other drying methods (Table7 & Fig 2). The impact of the different drying methods on their antioxidant recovery revealed that the peels dried using microwave possessed the highest levels of phenolic content , flavonoids , anthocyanin and tannins , followed by vacuum , hot air oven drying and then dehumidified air-drying , while the peels dried using sun drying had the lowest levels. Overall, microwave drying and vacuum drying were found to be the most suitable high levels of bioactive compounds.

All investigators reported that the higher activity of DPPH radical scavenging activity may be attributed to the presence of higher levels of total phenolic content as they play a key role as proton – donating ability and could serve as free radical inhibitors or scavengers, acting possibly as primary antioxidants .

Table 6: Antioxidant activity of different dried extract samples at different concentration to scavenge free radical of DPPH in comparison to ascorbic acid

Samples		Inhibitory percentage of DPPH radical (%inhibition) Concentration of banana peels extract (mg/ml)			
		0.50	**1.00**	**1.50**	**2.00**
Ascorbic acid		21.61±0.06	40.32±0.03	80.20±0.07	94.18±0.04
MD	**130W/8min**	13.61±0.05	21.54±0.04	40.80±0.03	59.28±0.02
	650W/7min	15.27±0.01	24.10±0.02	44.15±0.05	64.92±0.06
	950W/6min	15.40±0.04	24.46±0.01	44.95±0.02	65.22±0.08
VD	**65°C**	12.62±0.01	20.00±0.04	36.14±0.08	48.89±0.05
	100°C	10.77±0.03	18.08±0.02	33.17±0.09	46.29±0.01
HD	**70°C**	3.33±0.05	8.80±0.03	15.64±0.04	20.93±0.09
	110°C	9.97±0.01	17.55±0.07	30.45±0.01	40.50±0.03
DD	**30°C**	3.17±0.03	6.43±0.08	17.65±0.09	23.55±0.05
	45°C	3.92±0.01	6.88±0.03	18.50±0.02	24.40±0.02
	60°C	4.96±0.02	7.35±0.06	19.69±0.07	25.32±0.02
SD	**30-38°C**	0.00±0.01	5.23±0.06	16.06±0.02	20.10±0.06
F		67030.72			
P-Value		At the 0.001 level			

** Ascorbic acid was used as the reference material (Positive Control)*
*** P value is statistically highly significant at the 0.001 level.*
Note: MD: microwave dried samples; VD: Vacuum dried samples; HD: hot air dried samples
DD: Dehumidified dried samples; SD: Sun dried samples.

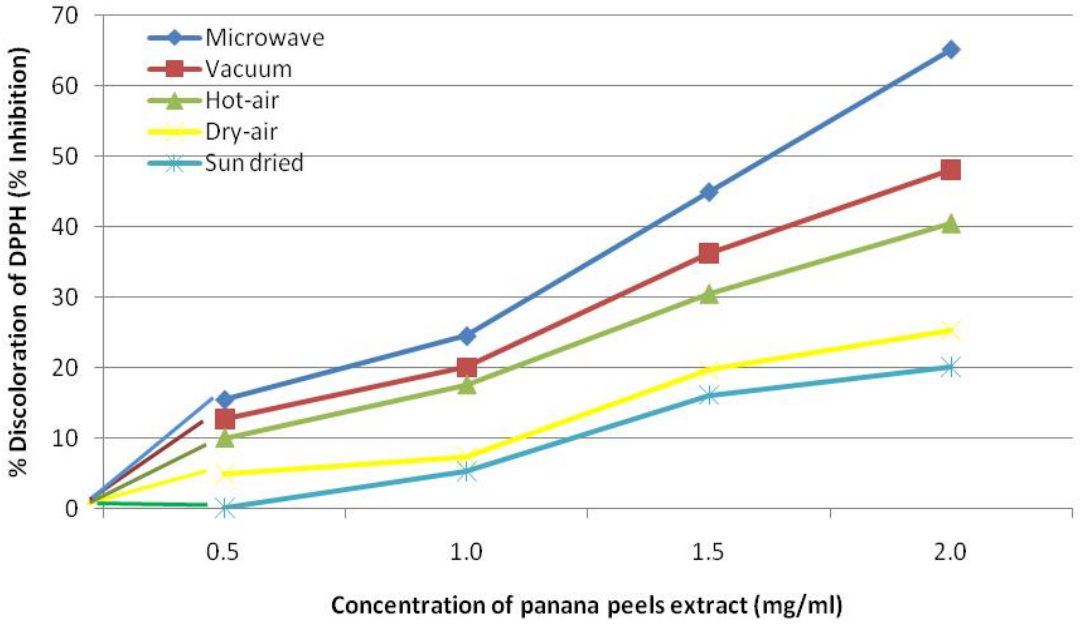

Fig. 1: Antioxidant activity of different dried extract samples of different drying methods

Table 7: Comparison of Antioxidant recovery (mg/g DM) of optimal drying condition samples for each method against other drying methods

Samples of optimal drying conditions	Bioactive compounds			
	TPC (mgGAE/g)	**TFC (mgQE/g)**	**TAC (mgCE/g)**	**TTC (mgTE/g)**
MD	26.88	31.81	5.34	22.00
VD	18.20	26.08	6.91	15.70
HD	16.22	12.97	3.09	14.37
DD	10.87	18.90	4.72	12.83
SD	7.80	9.96	1.94	5.56

Note: Optimal drying condition : MD 950W (6min); VD 65c° (8h) ; HD 110c (4h); DD 60c° (12h 30 min).

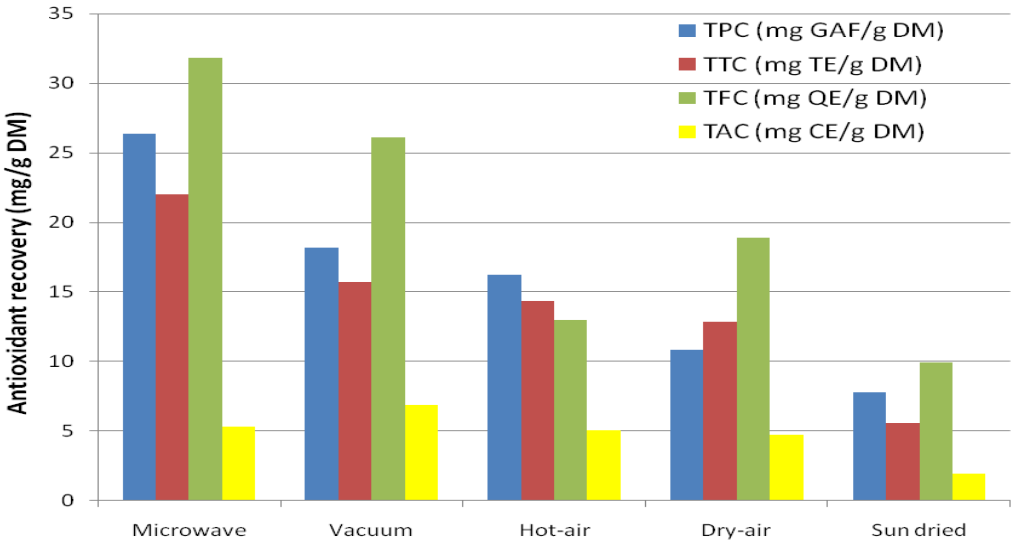

Fig. 2: Antioxidant recovery of different drying method

Antioxidant capacity:

Table (8) confirmed that the differences in the antioxidant capacity of different samples could related to the concentration of the high extent of phenolic compounds present which could be responsible for this parameter, indicating an antioxidant capacity lower in the samples possess lower bioactive content and higher in the samples possess higher content of these bioactive compounds (Contreras – calderon *et al.,* 2011).

The peels dried using microwave possessed the highest antioxidant capacity (37.34 -38.29 mg TE / g DM). This was followed by vacuum dryings, hot air-drying and then dry-air oven drying. Sun drying had the lowest antioxidant capacity.

Table 8: Total phenolic content and potent antioxidant capacity of banana peel samples dried by different methods:

Method of Drying		**Content (mgGAE/g)**	**Antioxidant capacity (mg Trolox eq/g DM)**
MD	**130W/9min**	26.06±0.05	37.34±0.05
	650W/7min	26.39±0.02	37.90±0.02
	950W/6min	26.88±0.03	38.29±0.01
VD	**65°C**	18.20±0.03	25.17±0.02
	100°C	13.11±0.06	18.02±0.04
HD	**70°C**	5.40±0.01	7.52±0.09
	110°C	16.22±0.03	21.96±0.03
DD	**30°C**	8.62±0.03	10.87±0.05
	45°C	9.22±0.02	12.00±0.01
	60°C	10.87±0.06	14.92±0.06
SD	**30-38°C**	7.80±0.01	11.00±0.05

Mean of triplicates ± standard deviation dry basis.

Antimicrobial activity :

In the present study, the antimicrobial effect of the extracts of different dried banana peels was studied on five diverse bacteria, yeast and fungus were shown in table (9). The diameter of inhibition zones (DIZ) for three concentrations from methanolic banana peels extract. The results showed that

80% methanol extract of microwave irradiation methods samples had the strongly effect than the samples of other drying methods, which inhibited species at 450 ppm against bacteria including *E. coli* (1.55cm), *S. aureus* (6.88cm) , *B. subtilis* (8.35 cm) , and yeasts, including *C. albicans* (0.95 cm) and fungus, including A.niger (8.74 cm) . In this study, *B. subtilis* was found to be more sensitive than *S. aureus* and *E. coli*. Also A.niger was sensitive in all broth dilution until 250 ppm. The last finding was in agreement with El-zawawy (2015) who revealed that banana peel extract has the best antifungal activity. Antimicrobial activity and preservative of banana peel extract are believed to be associated with phytochemical components of it, like phenolic and tannins as reported by Aboul-Enien *et al.,*(2016).

The current study appeared that the concentration of biologically active constituents due to the conditions of peel drying and polarity of the solvent used directly reflects this activity (Scariett and Vuong, 2017). Therefore banana peel has a valuable source for maintaining human health and can be of great significance in therapeutic treatments.

Table 9: Antimicrobial activity of methanol 80% extracts of different dried banana peel samples at three serial concentration

Method of Drying	Conc. mg/ml	Diameter of inhibition zone (cm)				
		Bacteria			Yeast	Fungus
		E. coli	*S. aureus*	*B. subtilis*	*C. albicans*	*A. niger*
MD	250	0.00	0.00	6.10±0.1	0.00	5.50±0.10
	350	1.28±0.02	5.59±0.02	7.22±0.07	0.82±0.01	7.00±0.05
	450	1.55±0.07	6.88±0.07	8.35±0.02	0.95±0.02	8.74±1.00
VD	250	0.00	0.00	4.07±0.05	0.00	4.11±0.03
	350	0.00	0.00	5.55±0.05	0.00	5.23±0.05
	450	1.00±0.05	4.70±0.01	6.37±0.03	0.78±0.03	6.90±0.05
HD	250	0.00	0.00	4.35±0.02	0.00	3.24±0.02
	350	0.60±0.06	3.80±0.09	4.86±0.10	0.60±0.05	3.80±0.05
	450	0.81±0.04	4.68±0.10	5.19±0.08	0.73±0.02	4.47±0.09
DD	250	0.00	0.00	3.00±0.03	0.00	3.00±0.06
	350	0.59±0.01	3.15±0.06	3.34±0.04	0.57±0.07	3.55±0.01
	450	0.77±0.02	3.49±0.05	4.65±0.04	0.68±0.03	4.11±0.05
	250	0.00	0.00	0.00	0.00	2.62±0.03
	350	0.00	0.00	0.00	0.00	2.86±0.01
	450	0.55±0.05	2.24±0.05	3.54±0.02	0.55±0.01	3.33±0.07

P-Value is statistically highly significant at the 0.001 level.
MD : microwave drying at 950 W; VD: Vacuum drying at 65c°; HD : hot-air drying at 110c°; DD: Dehumidified air-drying at 60c°; SD : Sun drying (30-38c°).

Conclusion

The present study was conducted with a view to exploit banana peel as a source of valuable components. The obtained results concluded that banana peel has high recovery yield of biochemical compounds and its contents are related with drying conditions. Among the five drying techniques tested, microwave method was found to be the most suitable for the dehydration of banana peels. The optimal drying conditions for retain higher levels of bioactive compounds with the most potent antioxidant capacity was 950 W for 6 min. Also, the obtained results confirmed that the large antimicrobial inhibitory, especially, evident with those dried microwave samples. Therefore, the microwave drying method is recommend for drying banana peels as a cheap and profitable a source of bioactive constituents and antioxidant activity.

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