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Research Article

EFFECTS OF MICROWAVE AND SUN DRYING ON THE CHEMICAL COMPOSITION, FUNCTIONAL, AND BISCUIT MAKING PROPERTIES OF SWEET ORANGE PEEL FLOUR

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ABSTRACT

Objective: The broad objective of the study was to determine the effects of microwave and sun drying on the chemical composition, functional, and biscuit making properties of sweet orange peel flour.

Methods: Peels were prepared from sweet orange fruits and cut into thin pieces. The peel pieces were dried in a domestic microwave oven at power outputs of 200, 400, 600, and 800 W. Flour samples were prepared from the dried peel pieces, evaluated for chemical composition and functional properties, and compared with of the sun dried sweet orange peel flour. Each of the flours was used to substitute 10% wheat flour in biscuits, which were assessed for the chemical composition, physical, and sensory properties.

Results: The microwave oven dried sweet orange peel flour contained higher amounts of ash, fat, fiber, and carbohydrate than the sun dried peel flour. The microwave drying decreased the total phenol content of the flour from 2.04 to 0.78 mg/g and the flavonoids content from 1.17 to 0.71 mg/g. The water absorption capacity, oil absorption capacity, and swelling capacity increased with the intensity of the microwave drying. The ash, crude fat, carbohydrate, fiber, and total phenol and flavonoids contents of the biscuits containing microwave dried peel flour were slightly ($p>0.0.5$) higher than those of the biscuits containing sundried peel flour. The diameter and height of the biscuits were not significantly ($p>0.05$) affected by the microwave oven drying. The spread ratio of the biscuit containing sun dried peel flour was 9.15 and decreased to a range of 7.530–5.595 for the biscuits containing microwave oven dried flour. The break strength and the weight of the biscuits increased with the power output of the microwave oven. The scores for flavor, texture, and overall acceptability of the biscuits containing sweet orange peel flour dried at 200 and 800 W were not significantly different ($p>0.05$). However, the scores for color and taste were higher for the biscuit containing the peel dried at higher power out puts (600 and 800 W) than the biscuits containing the peels dried at low power outputs (200 and 400 W).

Conclusion: It is concluded that microwave oven drying at 200 W improved the proximate composition and phytochemical contents but decreased the functional properties of the sweet orange flour. The biscuit containing sweet orange peel flour dried at 200 W was preferred to the others for the chemical composition, physical, and sensory properties.

Keywords: Microwave drying, Biscuit, Orange peel, Phytochemical composition, Sensory quality.

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INTRODUCTION

Sweet orange (*Citrus sinensis*) is one of the most important fruits in the tropical and subtropical regions of the world with a world production volume of 105 million metric tons per annum [1,2]. The fruits are eaten fresh but are also processed into canned orange juice, frozen juice concentrate, jams, and jellies among others [3]. During the processing of orange juice, substantial amount of peels is generated as by products. However, the peel contains high levels of carbohydrates, pectin, and fiber which lend it for use in increasing the viscosity, water, and oil absorption capacities of food systems [4]. The peel is also a good source of phytochemicals such as phenols, flavonoids, and carotenoids with excellent antioxidant properties [5,6]. Thus, the peel is a functional ingredient for formulation of food products. The use of the peel as a functional ingredient is important for consumers which are becoming interested in the health benefits of foods [7]. Consumers now look beyond the basic nutritional benefits to the potential disease prevention and health enhancing compounds contained in many foods [7]. However, for use in food products, the peels need to be processed into flour [8]. In the processing of sweet orange peels, the first step is to reduce its moisture content by drying. This inactivates enzymes that are responsible for degrading active compounds and decreases microbial growth [9]. However, the quality of the final dried product is strongly influenced by the techniques and the process variables used [10]. Plant materials are dried in a number of ways which include open air (shaded from direct), sun light, placing thin layers of food on drying frames, direct sunlight, drying ovens and solar dyers, direct fire, baking, lyophilization, microwaves, or infrared devices. Hot air is one of the most frequently used operations for drying of food. However, hot air drying takes longer time even at high temperature, which may cause damage to flavor, color, and nutrients in the dried products [9].

Recently, drying food using microwave has gained attention due to its heating rate, significant reduction in cooking time, more uniform heating, safe handling, and energy efficient [11]. The other advantages of microwave oven drying include space utilization, ease of operation, maintenance of sensory attributes, and little nutritional changes that occur in the process compared with conventional thermal applications [12]. Microwave heating is a sort of dielectric heating, which uses electromagnetic radiation in the frequency ranging from 300 MHz to 300 GHz [11]. The thickness, geometry, and dielectric properties of the food affect microwave heat transfer behavior [13]

Thus, the incorporation of microwave dried orange peel flour into wheat flour for the production of biscuit would enhance greater utilization of phytochemicals in Nigerian snacks. Biscuit is a snack which is eaten in-between meals or at any time of the day and by any age group. Biscuits contain fat (18.5%), carbohydrate (78.23%), ash (1.0%), and salt (0.85%) [14]. However, biscuits are prepared from wheat flour which is low in essential minerals, dietary fiber, and phytochemicals which are abundant in sweet orange peel [15,16]. Thus, such biscuits would be a carrier for these bioactive compounds in sweet orange peel [4]. The objectives of the study were to determine the proximate composition, phytochemical contents, and functional properties of microwave oven dried of sweet orange peel flours and compared with sun dried peel flour. The proximate composition, phytochemical contents, and sensory and physical properties of biscuits supplemented with the microwave and oven dried sweet orange peel flours were also determined.

METHODS

Procurement of raw materials

The sweet orange fruits were purchased from Kyado market, Benue State, Nigeria. Wheat flour, sugar, margarine, eggs, baking powder, and polyethylene for packaging were purchased from Wukari new market, Taraba State, Nigeria.

Microwave treatment of sweet orange peels

The fruits were washed thoroughly with water to remove dirt and adhering extraneous materials and peeled manually with a sharp kitchen knife. The sweet orange peels were cut into thin pieces (1 cm^2) in a tray and then heated in the domestic microwave oven (Triple Distribution System, M 1714, Korea) at output powers of 200, 400, 600, and 800 W as described by Adedeji *et al*. [17]. The peel pieces were also sun dried (32°C) in a tray to constant weight. The microwave and sun dried peels were milled in an attrition mill and sieved through 60 mesh size screens (0.01 mm). The flour samples were packaged in high-density polyethylene (HDPE) bags and stored at ambient temperature (30±2°C) before use.

Flour blending

Each of the microwave flours was used to substitute 10, 20, 30, and 40% of wheat flour in a food blender that was operated at full speed (1200 rpm) for 10 min. The flour blends were packaged in high-density polyethylene bags (HDPE) bags before use.

Preparation of biscuits

The biscuits were prepared following the methods described by Akubor [15]. The basic recipe used for the biscuit production consisted of wheat-flour (100 g), margarine (22 g), beaten egg (19 g), baking powder(1.8 g), water (45 ml), sugar (20 g), salt (0.3 g), and powdered milk (5 g). The ingredients were weighed and the dry ingredients were mixed together. The fat was rubbed in and mixed until the dough was formed. The resultant dough was kneaded and rested for 5 min. The rested dough was rolled into sheets and cut into shape using biscuit cutter. The dough were placed on well-greased baking trays and baked for 20 min in an oven pre-heated to 220°C, cooled to ambient temperature, and packaged in HDPE before use.

Evaluation of functional properties

The bulk density, water, and oil absorption capacities were determined as described by Onimawo and Akubor [18]. The swelling capacity was determined using the method of Adebowale *et al*. [19].

Proximate analysis

The moisture, ash, crude fat, crude fiber, and crude protein contents were determined as described by the AOAC [20] methods. The carbohydrate content was calculated by difference as described by the AOAC [20] method:

% Carbohydrate=100 – (% Moisture+% Ash+% Crude fat+% Crude fiber+% Crude protein).

Phytochemical analysis

The total phenols and total flavonoids contents of the flour and biscuits were determined as described by Okwu [21].

Evaluation of physical properties of biscuits

The height, length, width, and diameter of biscuit were determined using meter rule. The biscuit weight was determined using weighing balance [22]. The spread ratio of biscuit was calculated as diameter/height of biscuit. The break strength of biscuits was determined by subjecting the biscuit samples to various standard weights of 1, 3 5, 10, and 20 kg [22]

Sensory evaluation of biscuits

The sensory properties of the biscuits were assessed as described by Ihekoronye and Ngoddy [23]. A ten panel member randomly selected from the students and staff of the Department of Food Science and Technology, Federal University Wukari, Taraba State, Nigeria, was used for the sensory evaluation of the biscuits. The sensory evaluation was carried out in a sensory evaluation laboratory under adequate lightening and ventilation in the mid-morning (10 am). The biscuit samples were presented to the panelist in 3-digit coded plates. The order of presentation of biscuit samples to the panelists was randomized. The panelists were instructed to evaluate the coded samples for flavor, texture, color, taste, and overall acceptability. Each sensory attribute was rated on a 9-point Hedonic scale (where 1=disliked extremely and 9=liked extremely). The panelists were provided with distilled water to rinse their mouths in between evaluations.

Experimental design and statistical analysis

The experiment was carried out in completely randomized design. The data were analyzed by one-way analysis of variance using Statistical Package for the Social Sciences software version 20 [24]. Means where significantly different were separated by the least significant difference test. Significance was accepted at $p<0.05$.

RESULTS AND DISCUSSION

Proximate compositions of flours

The proximate composition of the sundried and microwave oven dried sweet orange peel flours is shown in Table 1. The moisture content of the sundried sweet orange peel flour (12.40%) was higher than that of the microwave oven dried sweet orange peel flour (5.34%). This was probably due to the high temperature of the microwave oven drying (400 W). The ash content of sweet orange peel flour was concentrated to 7.10% by the microwave drying due to the high temperature of the drying. Similarly, the microwave oven dried peel flour had higher levels of fat and fiber than the sun dried peel flour. However, the microwave dried peel flour had lower protein and carbohydrate contents than the sundried flour. The high temperature of the microwave oven drying probably destroyed the protein by denaturation and reduced the protein content in the flour. The increase in the fat and fibers contents was probably due to concentration effect of the microwave oven drying. The carbohydrate in the peel was probably involved in Maillard reactions between the amino groups of protein and the reducing sugars in the presence of heat during the microwave oven drying. The high amount of fiber in the microwave oven dried flour is significant for human nutrition. Fibers bind to bile acids in the small intestine which prevents them from entering the body thereby lowering the cholesterol levels in the blood [25]. Soluble fibers have been documented to attenuate the absorption of sugars, reduce sugar response after eating, and normalize blood lipid levels [26]. They are reported to produce short-chain fatty acids as by-products when fermented in the colon [26].

Table 1: Proximate composition of sun and microwave oven dried sweet orange peel flours

Parameters (%)	Sun dried sweet orange peel four	Microwave oven dried sweet orange peel flour
Moisture	$12.46^{a}\pm0.03$	$5.13^{b}\pm0.02$
Ash	$3.34^{b}\pm0.04$	$7.10^{a}\pm0.07$
Protein	$7.22^{e}\pm0.0.04$	$5.91^{b}\pm0.04$
Fat	$1.46^{b}\pm0.04$	$5.20^{a}\pm0.02$
Fiber	1.38b±0.04	$7.09^{a}\pm0.05$
Carbohydrate	$74.14^{a}\pm0.06$	$69.57^{b}\pm0.12$

Values are means±standard deviation of three replications. Means with the same superscript within a row were not significantly different ($p>0.05$). Microwave oven drying was carried out at 200 W

Phytochemical composition of orange peel flour

The phytochemical composition of the sun and microwave oven dried orange peel flours is shown in Table 2. The phenol and flavonoids contents of the peel flour were significantly affected by microwave oven drying. The phenol and flavonoids contents of the sun dried peel flours were 0.78 and 0.71, respectively. The total phenol contents decreased with the intensity of the microwave oven heating where the values decreased from 2.04 to 0.45 mg/g. Similarly, the flavonoids content of the peel decreased from 1.17 mg/g for the peel dried at 200 W to 0.23 mg/g for the 800 W dried peel flour. The decrease in the phenol contents of the flours may be due to thermal destruction during microwave oven drying [11,27,28]. Youssel and Mokhtar [9] reported that thermal destruction of polyphenols affects the integrity of the cell structure which resulted in migration of components. This led to losses by leaching. Thermal break of polyphenols could also cause breakdown in various chemical reactions involving enzymes, light, and oxygen [9,13]. According to Mediani *et al.* [29], the decrease in total phenols content during heating can be attributed to the binding of polyphenols with other compounds like proteins or to the alteration in the chemical structure of polyphenols which decreased their extraction. Medani *et al.* [29] suggested that many factors other than heat treatment influence the destruction of polyphenols. These include the activities of polyphenol oxidase, organic acid content, sugar concentration, and pH. Ramful *et al.* [8] reported that phenols are reducing agents that protect the body tissues against oxidative stress. The decrease in flavonoids contents was due to thermal destruction of flavonoids [28]. Sawalha *et al.* [31] reported that citrus peels are very rich in phenolic and flavonoid compounds. Flavonoids are the most common and widely distributed group of plant phenolics and are among the most potent antioxidants [5]. Some flavonoids scavenge super oxides whereas other flavonoids scavenge the highly reactive oxygen derived radical called peroxynitrite [6]. Rutin, a type of flavonoid, is known for its anti-inflammatory and vasoactive properties [32]. It also has the capability to diminish capillary permeability and to reduce the risk of arteriosclerosis which reduces coronary heart disease through diminishing of platelet aggregation [32].

Functional properties of orange peel flours

The effects of microwave oven drying on the functional properties of sweet orange peel flour are shown in Table 3. The water absorption capacity of the sun dried sweet orange peel flour was 221%. The water absorption capacity increased from 178% for the 200 W dried peel flour to 226% for the 800 W dried peel flour. Only microwave oven drying may have exposed the hydrophilic groups of the carbohydrate and protein molecules in the flour, which gave the high water absorption capacity [10]. The heating may have also compacted the starch molecules at the low microwave oven heating (200–400 W) [33]. This probably blocked the pores of flour tissues which hindered water slippage and retention [33]. Thus, the high microwave heating (600–800 W) probably caused the loosing of the structure of the starch molecules [34]. Loose starch structure has been reported to give high water absorption capacity [22]. Compression of cellular appearance in microwave oven dried sample at 600 W was reported by Yi *et al.* [10]. Guillon and Champ [35] suggested that the 600 and 800 W heating produced higher water absorption capacity than the sun dried flour. The high-power outputs (600–800 W) of the water absorption capacity are a function of fiber structure rather than chemical composition of the food. The power outputs of microwave drying were reported to affect the fiber structure which was related to the change in the water absorption capacity [11]. The high water absorption capacity of flour makes it useful functional ingredient to prevent syneresis, modify texture and viscosity, and reduce calories of food formulations [10]. High water absorption capacity gives food products good texture which reduces retrogradation and syneresis during storage, retorting and freezing of food products [15].

Table 2: Effect of microwave oven drying on the phytochemical composition of orange peel flour

Dried sweet orange peel flour	Total phenol (mg/g)	Total flavonoids (mg/g)
Sun dried peel flour	0.78^{c}±0.06	0.71^{b}±0.04
200 Watts dried flour	2.04^{a}±0.01	1.17^{a}±0.03
400 Watts dried flour	1.86^{b}±0.02	0.70^{b}±0.01
600 Watts dried flour	0.56^{d}±0.05	0.52^{c}±0.02
800 Watts dried flour	0.45^{d}±0.1	0.23^{d}±0.12

Values are means±standard deviation of three replications. Means with the same superscript within a column were not significantly different (p>0.05)

In general, the oil absorption capacity increased with the level of the microwave heating. The oil absorption capacity increased from 104 to 196% at 600 W and decreased to 191 at 800 W of heating. The oil absorption capacities of the microwave dried flours were lower than those of the sun dried flour for only the flours dried at 200 and 400 W. Heat treatments such as microwave drying altered the polysaccharide and protein contents and consequently the water and oil absorption capacities of flour [17]. Oil absorption capacity is useful in food preparations like bakery products where oil is an important ingredient [22]. In the present study, at any temperature of drying, the water absorption capacity of the flour was higher than the oil absorption capacity. There may be more of the hydrophilic groups relative to the hydrophobic groups in the sweet orange peel flour [16].

The swelling capacity of the sun dried sweet orange peel flour was 580% while the swelling capacities of the microwave oven dried peel flours varied from 579 to 622%. The swelling capacities of the microwave oven dried peel flours except that dried at 200 W were higher than those of the sundried (control) peel flour. The increase in swelling capacity may be due to increase in water absorption capacity of the peel flour with increase in the intensity of the microwave drying. The microwave drying probably decreased intragranular binding forces which enhanced water absorption and thus the swelling capacity [18]. However, the bulk density of the sundried peel flour (0.71 g/cm^3) was higher than those of the microwave oven dried flours (0.54–0.70 g/cm^3). The microwave oven drying probably caused gelatinization of the starch which increased the porosity of the starch [17]. Flours with low bulk density are recommended for use in the formulation of complementary foods [4].

Proximate composition of biscuits

The proximate composition of biscuits supplemented with sun and microwave oven dried sweet orange peel flour is shown in Table 4. The moisture content of the microwave dried four (3.76%) was lower than that of the sun dried biscuit (4.70%). The higher moisture content of

Table 3: Effects of microwave oven drying on the functional properties of orange peel flour

Drying conditions (W)	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling capacity (%)	Bulk density (g/cm^3)
Sun dried peel flour	221^{c}±0.13	142^{c}±0.12	580^{d}±0.09	0.71^{a}±0.2
200 W dried peel	178^{e}±0.13	104^{e}±0.07	579^{e}±0.10	0.54^{a}±0.10
400 W dried peel	186^{d}±0.16	106^{d}±0.16	589^{c}±0.03	0.64^{a}±0.01
600 W dried peel	241^{a}±0.07	196^{a}±0.02	617^{b}±0.07	0.70^{a}±0.09
800 W dried peel	226^{b}±0.11	191^{b}±0.03	622^{a}±0.06	0.66^{a}±0.09

Values are means±standard deviation of three replications. Means within a column with the same superscript were not significantly different (p>0.05) the sun dried orange peel flour-based biscuits could be attributed to the high moisture content of the sundried orange peel flour (Table 1). The moisture contents of the biscuits were lower than 6.40% reported by Nwosu and Akubor [16] for biscuits supplemented with orange flour. Biscuits are generally low in moisture content. Therefore, the moisture contents of the orange peel-based biscuits would ensure shelf stability if the biscuit appropriately packaged [43]. The biscuit containing microwave dried flour was higher in ash, fat, carbohydrate, and fiber but lower in protein contents, though, not significantly different (p>0.05). The prolonged sun drying may have caused thermal breakdown of fat. However, the content of fat in biscuits is important for infant diet which should contain essential fatty acids for promotion of good health [36]. Fat is a carrier of fat soluble vitamins and is useful for promotion of the absorption of Vitamin A and carotene [36]. The lower protein content of the microwave oven dried orange peel flour-based biscuit could be attributed to thermal destruction [11,13]. The heat might have denatured the proteins. However, orange peels are not known to be a good source of protein which probably contributed to the low-protein content of the biscuits. Nwosu and Akubor [16] reported low-protein content of 2.67% in sweet orange peel flour. Nwosu and Akubor [16] reported that the difference in the protein contents of orange peels could be due variety and the geographical location.

The biscuits had high crude fiber contents (8.15–8.89%) when compared to mango-based biscuit that contained 2.40% [37]. Thus, the biscuits are good source of fiber which is significant in human nutrition. Anderson *et al*. [25] reported that fiber changes how other nutrients and chemicals are absorbed in the body. Fibers bind bile acids in the small intestine and prevent them from entering the body [25]. This lowers cholesterol levels in the blood [25]. Soluble fibers attenuate the absorption of sugars, reduce sugar response, and normalize blood lipid levels. They produce short-chain fatty acids as by-products when fermented in the colon [26]. The short-chain fatty acids are involved in stabilizing blood glucose levels by acting on pancreatic insulin release and liver control of glycogen breakdown, etc. [38]. The higher carbohydrate content of the microwave oven dried orange peel flour was due to concentration by the microwave heating. Ash is a measure of the mineral content of a food, and thus, orange peel flour may be considered rich in mineral constituents. Magda *et al*. [39] reported similar content of 4.24% ash in orange peel flour.

Phytochemical composition of biscuits

The phytochemical contents of the biscuits are presented in Table 5. The phytochemical contents of the biscuits were lower than those of the flours shown in Table 2 due to destruction by the baking heat. Like those of the flours, the phytochemical contents of the biscuits decreased with the power output. The phenol and flavonoid contents of all the biscuits were higher than 0.01and 0.4 mg/g reported for phenol and flavonoid contents, respectively, of wheat flour biscuits [4]. Studies have shown that the use of orange peels is associated with low risk of several degenerative diseases such as cancers and cardiovascular diseases due the different antioxidant components such as phenols and flavonoids among others it contains [5,16]. The results in Table 5 show that microwave drying of sweet orange peels at 200 and 400 W retained more of the phenol and flavonoids contents of biscuits supplemented with the peel flour than the other drying methods used.

Physical properties of the biscuits

Table 6 shows the physical properties of biscuits supplemented with the microwave oven dried sweet orange peel flours. The diameter and thickness (height) of the biscuit were not significantly affected by microwave oven drying. The diameter of the control (biscuit containing sun dried) was 4.490 cm and a range of 3.975–4.53 cm for the biscuits containing microwave dried peel flours. However, the spread ratio decreased from 9.15 for the control to 7.53–5.71 for the biscuits containing microwave oven dried flours. The break strength and the weight of the biscuits increased with the intensity of the microwave oven heating of the peels. The break strength of the control was 1.05 kg. The break strength increased from 3.03 kg for the biscuits containing peel heated at 200 W to 5.02 kg for the biscuit containing 800 W heat peel flour. The higher spread ratio of the sun dried sweet orange peel flour was due to its lower fiber content (Table 1) which caused the flour to absorb less water. This did not increase the viscosity but increase the spread ratio during the baking [40]. Thus, the decrease in the spread ratio of the biscuits containing the microwave dried peel flours may be related to the increased water absorption capacity of the microwave oven dried flours in the dough. This increased the viscosity of the dough and decreased the spread ratio of the biscuits. Spread ratio is a function of available water [18]. The biscuit containing 600 W heated peel flour was thicker than the others which explained why it had the highest break strength and weight. This could be attributed to the high moisture and crude fiber contents of the microwave dried flour (Table 1).

Sensory properties of biscuits

The sensory properties of biscuits supplemented with the microwave oven dried sweet orange peel flours are shown in Table 7. The scores for color of the biscuits increased with the power output. The scores for taste of the biscuits were higher for the biscuits prepared with the sweet orange peel flour heated at high-power outputs (600 and 800 W) than those at the low-power outputs (200 and 400 W). Similar trends were exhibited for the scores for flavor, texture, and overall acceptability of the biscuits. However, the scores for all the attributes were lower for the biscuits prepared with the peel flour heated at 400 W than the other biscuits. The biscuits were unattractive to the consumers because color, texture, and flavor are critical sensory attributes that affect consumer acceptance. The sensory properties are influenced by method of preparation, formulations, processing, and storage conditions [22]. The high-power outputs of 600 and 800 W may have caused non-enzymatic browning reactions (Maillard reactions) between proteins and carbohydrates that generated products which improved the color, taste, and flavor of the biscuits [18]. At mild microwave oven drying (200 and 400 W), the dried products probably retained the color and taste of the array of phytochemicals in the peel which were probably destroyed at high heating conditions (600 and 800 W). This makes drying the peel at low-power output important since surface color of baked goods is the first quality parameter evaluated by consumers and is very important for the initial acceptability The high microwave

Table 4: Effect of microwave oven drying on the proximate composition of biscuits supplemented with sweet orange peel flour

Nutrient (%)	Sun dried sweet orange peel flour	Microwave oven dried sweet orange peel flour
Moisture	4.70[a]±0.03	3.76[b]±0.16
Ash	4.40[b]±0.11	5.62[a]±0.13
Crude fat	5.56[b]±0.11	6.00[a]±0.18
Crude protein	6.51[a]±0.07	6.24[b]±0.14
Carbohydrate	6.67[b]±0.06	6.73[a]±0.12
Crude fiber	8.15[b]±0.06	8.89[a]±0.10

Values are means standard deviation of three replications. Means within a column with the same superscript were not significantly different (p>0.05). Microwave oven drying was carried out at 200 W. The biscuits contained 10% of the sun and microwave dried flours

Table 5: Effect of microwave oven drying on the phytochemical composition of orange of biscuits supplemented with sweet orange peel flour

Dried sweet orange peel flour	Total phenol (mg/g)	Total flavonoids (mg/g)
Sun dried peel flour	0,45[c]±0.02	0.31[c]±0.06
200 W dried flour	1.90[a]±0.08	1.05[a]±0.00
400 W dried flour	1.07[b]±0.024	0.61[b]±0.07
600 W dried flour	0.40[c]±0.01	0.30[c]±0.01
800 W dried flour	0.33[c]±0.09	0.21[c]±0.08

Values are means±standard deviation of three replications. Means with the same superscript within a column were not significantly different (p>0.05)

Table 6: Physical properties of biscuits supplemented with sun and microwave dried sweet orange peel flour

Physical properties	Sun dried peel flour	200 W dried peel flour	400 W dried peel flour	600 W dried peel flour	800 W dried peel flour
Diameter (cm)	4.40[a]±0.01	4.48[a]±0.04	3.98[a]±0.06	4.05[a]±0.02	4.52[a]±0.03
Height (cm)	0.52[a]±0.02	0.61[a]±0.06	0.69[a]±0.01	0.72[a]±0.02	0.62[a]±0.03
Spread ratio	9.15[a]±0.20	7.52[b]±0,10	5.95[c]±0.07	5.71[c]±0.04	7..53[b]±0.01
Break strength (kg)	1.05[d]±0.07	3.03[c]±0.05	4.08[b]±0.03	5.04[a]±0.07	5.02[a]±0.01
Weight (g)	5.74[c]±0.05	6.45[b]±0.02	7.08[a]±0.03	7..43[a]±0.06	7.58[a]±0.03

Values are means±standard deviation of three replications. Means within a row with the same superscript were not significantly different (p>0.0)

Table 7: Mean sensory scores of the biscuits supplemented with microwave oven dried sweet orange peel flour

Biscuits (level of heating, W)	Color	Taste	Flavor	Texture	Overall acceptability
200	7.00	6.10	7.40	8.00	7.60
400	7.00	5.90	6.40	6.80	6.50
600	7.90	7.30	7.20	7.00	7.30
800	8.40	7.30	7.20	7.20	7.20

Means within a column with the same superscript were not significantly different (p>0.05)

drying (600 and 800 W) may have compacted the starch structure of the biscuits which increased the hardness, an essential property of biscuit that contributes to product quality. The results of this study were in agreement with the report that the information on the sensory and functional properties are essential for process design, evaluation, quality control, and consumer acceptability of food products [41].

CONCLUSION

The chemical composition and functional properties of sweet orange peel were affected by microwave oven drying. The microwave drying increased the ash, fat, protein, crude fiber, and carbohydrate but decreased the total phenol and flavonoids contents of the peel flour. Only heating at 600 and 800 W increased the functional properties of the peel flour over those of the sun dried flour. However, the physical and sensory properties of the biscuits were not adversely affected by microwave oven drying. In general, biscuit containing 200 W dried peel was preferred to the other biscuits. The biscuit containing 10% of the 200 W microwave dried peel flour had higher proximate composition, phenol and flavonoids contents than the biscuits containing sun dried sweet orange peel flour.

REFERENCES

1. Padharipande S, Makode H. Separation of oil and pectin from orange peel and study on effect of pH of extracting medium on the yield of pectin. J Eng Res Stud 2012;3:1-4.
2. Food and Agriculture Organization. Citrus Fruit Statistics. Rome, Italy: Food and Agriculture Organization of United Nation; 2016.
3. Ali AH, Hassan A. Study on some macronutrient composition in peels of different citrus fruits grown in Pakistan. J Chem 2010;32:83-6.
4. Akubor PI. Functional properties of sweet orange peel and pulp flours, wheat flour and their blends. FUW J Agric Life Sci 2019;3:213-30.
5. Goulas V, Manganaris GA. Exploring the phytochemical content and the antioxidant potential of *Citrus* fruits grown in Cyprus. Food Chem 2012;131:39-47.
6. Barros H, Ferreira RD, Genovese MI. Antioxidant capacity and mineral content of pulp and peel from commercial cultivars of *Citrus* from Brazil. Food Chem 2012;134:1892-8.
7. Hasler CM. Regulation of Functional Foods and Nutraceuticals. A Global Perspective. Iowa, USA: IFT Press and Blackwell Publisher; 2003. p. 24-34.
8. Ramful D, Bahorunb T, Bourdonc E, Tarnusc E, Aruoma OI. Bioactive phenolics and antioxidant propensity of flavedo extracts of Mauritian *Citrus* fruits: Potential prophylactic ingredients for functional foods application. Toxicology 2011;278:75-87.
9. Youssel KM, Mokhtar SM. Effect of drying methods on the antioxidant capacity, color and phytochemicals of *Potulaca oleracea* L leaves. J Nutr Food Sci 2014;4:2-6.
10. Yi T, Fang Y, Wang K, Huang X. Influence of drying methods on the functional properties of dietary fiber. J Chem Pharm Res 2014;6:2887-94.
11. Arslan D, Ozcan MM. Study the effect of sun, oven and microwave drying on quality of onion slices. LWT Food Sci Technol 2010;43:1121-227.
12. Krokida MK, Maroulis ZB. Effect of microwave drying on some quality properties of dehydrated products. Drying Technol 1999;17:449-66.
13. Maskan M. Microwave/air and microwave finish drying of banana. J Food Eng 2000;44:1-10.
14. Agu HO, Ezeh GC, Jideani AI. Quality assessment of acha-based biscuit improved with Bambara nut and unripe plantain. Afr J Food Sci 2014;8:278-9.
15. Akubor PI. Chemical composition, physical and sensory properties of biscuits supplemented with cashew pomace flour. NSUK J Sci Technol 2016;6:138-41.
16. Nwosu AN, Akubor PI. Health promoting potentials of biscuits produced with orange peel and pulp flours. J Nutr Ecol Food Res 2016;3:43-8.
17. Adedeji OE, Ezekiel OO, Akubor PI. Effect of alkali and microwave pretreatments on the functional properties of orange and plantain peel flours. FUW J Agric Life Sci 2017;1:1-12.
18. Onimawo IA, Akubor PI. Food Chemistry (Integrated Approach with Biochemical Background). 2nd ed. Agbowo, Ibadan, Nigeria: Joytal Printing Press; 2012.
19. Adebowale YA, Adeyemi IA, Oshodi AA. Functional and physicochemical properties of flours of six *Mucunu* species. Afr J Botechnol 2005;4:1461-8.
20. Association of Official of Official Analytical Chemists. Official Methods of Analysis. United States: Association of Official of Official Analytical Chemists; 2010.
21. Okwu DE. Phytochemical and vitamin contents of indigenous spices of Southeast Nigerian. J Sustain Agric Environ 2004;6:30-7.
22. Akubor PI, Ukwuru MU. Functional properties and biscuit making potential of soybean and cassava flour blends. Plant Foods Hum Nutr 2003;58:1-12.
23. Ihekoronye AI, Ngoddy PO. Integrated Food Science and Technology for the Tropics. London: Macmillan Press Publisher; 1985. p. 193-234.
24. SPSS. Statistical Package for Social Sciences (SPSS) Version 17. Chicago, IL, USA: SPSS Inc.; 2007.
25. Anderson JW, Baird P, Davis RH. Health benefits of dietary fiber. Nutr Rev 2009;67:188-205.
26. Weicker MO, Pfeiffer AI. Metabolic effects of dietary fiber consumption and prevention of diabetes. J Nutr 2008;138:439-42.
27. Adeyemi SB, Ogundele KO, Animasaun MA. Influence of drying methods on the proximate and phytochemical composition of *Moringa oelifera* Lam. Glob J Med Plant Res 2014;2:15.
28. Hayat K, Zhang X, Farooq U, Abbas S, Xia S. Effect of microwave treatment on phenolic content and antioxidant activity of citrus mandarin pomace. Food Chem 2010;123:423-9.
29. Mediani A, Abas F, Tan CP, Khatib A. Effects of drying methods and storage time on free radical scavenging activity and total phenoloic content of Cosmos caudatus. Antioxidants 2014;3:358-70.
30. Amarowicz R, Carle R, Dongwoski G, Durrazk A, Galensa R, Kammera D, *et al*. Influence of post harvest processing and storage on the content of phenolic acids and flavonoids in foods. Mol Nutr Food Res 2009;53:151-83.
31. Sawalha SM, Arráez-Román D, Segura-Carretero A, Fernández-Gutiérrez A. Quantification of main phenolic compounds in sweet and bitter orange peel. Food Chem 2009;116:567-74.
32. Jiang P, Burcynski F, Ctria JA, Campbell C, Pierce G, Austria JA, *et al*. Rutin and flavonoids contents in the three buckwheat species and their protective effects against lipid peroxidation. Food Res Int 2007;40:356-64.

33. Niba LL, Bakonga MM, Jackson EL, Schlimme DS, Li BW. Physicochemical properties and starch granule characteristics of flour from various *Manihot esculenta* (cassava) genotypes. J Food Sci 2001;67:1701-5.
34. Mallek-Ayadi S, Bahloul N, Kechaou N. Characterization, phenolic compounds and functional properties of *Cucumismelo* L. peels. Food Chem 2017;221:1691-7.
35. Guillon F, Champ M. Structural and physical properties of dietary fibres, and consequences of processing on human physiology. Food Res Int 2000;33:233-45.
36. Bogert JL, Briggs GM, Galloway DH. Nutrition and physical fitness. Int J Food Sci Nutr 1994;45:225-30.
37. Fowomola MA. Some nutrients and antinutrients contents of mango *(Mangifera indica*) seeds. Afr J Food Sci 2010;4:472-6.
38. Wong JM, de Souzu RO, Kendall CW, Emman A, Jenkins DJ. Colonic health: Fermentation and short chain fatty acids. J Clin Gastroenterolo 2006;40:235-43.
39. Magda RA, Awad AM, Selim KA. Evaluation of mandarin and navel orange peels as natural sources of antioxidants in biscuit. J Food Sci Technol 2008;5:75-82.
40. Khattack M, Muzaffa AK. Ingredients and chemical composition of biscuit available in Peshawar and Murdan divisions. Sarhad J Agric 2003;19:279-83.
41. Akubor PI, Nwosu AN. Acceptability and storage stability of biscuits produced with orange peel and pulp flours. J Environ Sci Toxicol Food Technol 2018;12:8-15.