INNOVARE JOURNAL OF FOOD SCIENCE

NNOVARE ACADEMIC SCIENCES
Knowledge to Innovation

ISSN;2321;550X

Vol 8, Issue 3, 2020

Research Article

PHYTOCHEMICAL COMPOSITION AND PHYSICAL AND SENSORY PROPERTIES OF BISCUITS SUPPLEMENTED WITH SUN- AND OVEN-DRIED SWEET ORANGE PULP FLOURS

AKUBOR PI[1]*, IHOTU J[2]

[1]Department of Food Science and Technology, Federal University Wukari, Taraba State, Nigeria. [2]Department of Food Science and Technology, University of Umkar, Umkar, Benue State, Nigeria. Email: akuborpeter@gmail.com

Received: 27 March 2020, Revised and Accepted: 19 April 2020

ABSTRACT

Objective: The objective of the study was to assess the phytochemical composition and physical and sensory properties of biscuits supplemented with sun- and oven-dried sweet orange pulp flours.

Methods: The sweet orange (*Citrus sinensis*) was washed in distilled water, peeled manually and the juice was extracted. The pulp was separated from the seeds and then cut into pieces. A portion of the pulp was sun dried (32°C) and the second portion was oven at 60°C to constant weight. The dried pulp samples were milled and sieved through 500 µm sieve and analyzed for phytochemical composition. The sun- and oven-dried flour samples, respectively, were used to substitute 20% of wheat flour. Biscuits were prepared from the flour blends and evaluated for the phytochemical composition and physical and sensory properties.

Results: The saponin, carotenoid, phytate, and terpenoid contents of the sun-dried sweet orange flour were higher than those of the oven-dried sweet orange flour. However, the oven pulp flour had higher amounts of total phenol and flavonoids than the sun-dried sweet orange pulp flour. The phytochemical contents of the biscuits supplemented with sweet orange pulp flours were lower than those of the pulp flours. The biscuit supplemented with the sun-dried sweet orange pulp flour contained higher amounts of total phenol, saponins, and phytates than the biscuit supplemented with oven-dried sweet orange pulp flour. The diameter, height, weight, volume, and spread ratio of the biscuits supplemented with sun- and oven-dried sweet orange pulp flours were not significantly different ($p>0.05$). The scores for color, flavor, texture, and overall acceptability of the biscuits containing sun- and oven-dried sweet orange pulp flours were not significantly different ($p>0.05$). However, the biscuit containing oven-dried sweet orange pulp flour was rated significantly higher ($p<0.05$) for texture.

Conclusion: The biscuits supplemented with sun-dried sweet orange pulp flour contained higher amounts of saponins and phytates but lower amounts of flavonoids, carotenoids, and terpenoids than the biscuits supplemented with oven-dried sweet orange pulp flour. The physical and sensory properties of the biscuits supplemented with sun- and oven-dried sweet orange pulp flours were not significantly different. However, the biscuit containing oven-dried sweet orange pulp flour was rated higher in all the sensory attributes except texture.

Keywords: Biscuits, Orange, Pulp, Drying, Phytochemicals.

INTRODUCTION

Sweet orange (*Citrus sinensis*) is a member of the family *Rutaeae*. The tree is the most widely grown *Citrus* tree in the world [1]. In terms of volume of production, *Citrus* ranks after banana as the world second fruit crop with more than 108 million tons [1]. The tree is an evergreen flowering tree that generally grows to 9–10 cm or more in height. The tree produces fruits which are mainly processed to juice while the pulp and seeds are generally thrown away as waste. However, the rind, albedo, pulp, and seeds which are approximately 50% of the fruits contain varying amounts of water, soluble sugars, fiber, organic acids, amino acids, proteins, minerals, oils, vitamins, and essential phytochemicals such as flavonoids [2]. The citrus pulp is a rich source of fiber and essential phytochemical with antioxidants activity [3]. Phytochemicals are non-nutritive plant chemicals that have either protective or disease protective properties [4]. Dietary intake of phytochemicals promotes health benefits by protecting against chronic degenerative disorders such as cancer, cardiovascular, and neurodegenerative diseases [4,5]. The role of fiber in sustaining good health has been stressed. The benefits ascribed to fiber in diets include the promotion of digestive health and weight loss, control of blood sugar levels, and prevention of type 2 diabetes [6], fibers also have the potential of lowering cholesterol and indirectly prevent heart disease and stroke [7]. The sweet orange pulp with high nutraceutical potential is used to produce jams and marmalades [3]. However, the pulp could be processed into flour and used in similar manner other flours are used.

To extend the shelf life of sweet orange fruit pulp for further use, it is essential to preserve the pulp using simple and inexpensive preservation method. Drying is a common preservation method used for foodstuffs and the quality of the final products is dependent on the technique and the process variables used [8]. Drying of sweet orange pulp would be provided a technologically sound base for the use of the pulp in a variety of ways. Sun drying of agricultural products is the traditional method employed in most of the developing countries. It offers a cheap method of drying but often results in inferior quality of products due to its dependence on weather conditions [9]. It exposes the products to dirt, damage by insects, bacteria infestation, and deposition of fungal spores [10]. Hot air drying is one of the most frequently used operations for food dehydration. However, hot air drying takes long time even at high temperature which can accelerate reactions that adversely affect product quality [11]. However, drying is considered a beneficial way to protect the phytochemical contents of foods [8]. However, most phytochemicals are sensitive to oxidation, which potentially occurs during drying process. The stability of phytochemicals can be affected by the presence of oxygen, different temperature, light, water activity, pH, and pro-oxidants (enzymes and metals) [12]. It also has the advantage of reducing the cost of final product as transportation and storage costs are determined by product weight. Information on the effect of sun and oven drying on the quality of sweet orange pulp is scanty.

Biscuits are widely consumed throughout the world. Biscuits are priced for their taste, aroma, and texture. Wheat flour which is used for producing biscuit is low in fiber and phytochemical contents. Since sweet orange pulp is reported to be a good source of fiber and phytochemicals [3], its flour could help in boosting the fiber and phytochemical levels of baked products such as biscuits. Therefore, the broad objective of this study was to determine the quality of biscuits supplemented with sun- and oven-dried sweet orange pulp flours.

METHODS

Procurement of raw materials

Fresh sweet orange fruits (Washington variety), which were identified at the Department of Crop Science, Akperan Orshi College of Agriculture, Yandev, Benue State, were used for the study. Wheat flour (soft), sugar, margarine, baking powder, eggs, and table salt were purchased from Gboko Main Market, Benue State, Nigeria.

Preparation of wheat flour

The commercial wheat flour was sieved through a 500 μm mesh screen and packaged in high-density polyethylene (HDPE) bags before use.

Preparations of sweet orange pulp flours

The sweet orange fruits (1.2 kg) were cleaned by washing thoroughly with distilled water. The orange fruits were peeled manually with a sharp knife. The orange fruits were pressed to extract the juice. The pulps were separated from the seeds and were further pressed to remove excess juice. The pulp was then soaked in water for 2 min. The water was pressed out gently and the pulp was shredded into thin slices and then used as follows:

Preparation of sun-dried sweet orange pulp flour

The pulp slices were sun dried (32°C) to constant weight, milled, sieved through a 500 μm screen, and packaged in HDPE bags before use [3].

Preparation of oven-dried sweet orange pulp flour

The pulp slices were oven dried at 60°C for 10 h, milled and sieved through a 500 μm mesh screen, and then packaged in HDPE bags before use [3].

Flour blending

Each of the sun- and oven-dried flour samples was used to substitute 20% of wheat flour in a Kenwood food processor that was operated at full speed (1200 rpm) for 10 min. The choice of 20% level of substitution was based on the previous reports [13,14]. The flour blends were packaged in HDPE bags before use.

Preparation of biscuits

The biscuits were prepared using the straight dough method as described by Akubor (Table 1) [15]. The ingredients used were 49.5%, 20% margarine, 10% homogenized whole egg, 20% sugar, and 0.5% baking powder. The ingredients were weighed and thoroughly mixed manually. The wet ingredients were first mixed in a mixing bowl at an evenly low speed for 5 min. Then, the dry ingredients were added and the mixing was continued at a higher speed until uniform texture was obtained. The dough sample was then manually kneaded, molded, shaped, and placed on the baking tray. The dough was then weighed and baked in a thermostatically controlled baking oven at 170°C for 20 min. The biscuits produced were cooled to ambient temperature (32°C) and packaged in polyethylene bags before analysis. The biscuits were produced in three replicates. About 100% wheat flour biscuit served as the control.

Sensory evaluation of biscuits

A 10 panel member randomly selected from the students and staff of the Department of Food Science and Technology, University of Mkar, Benue State, Nigeria, was used for the sensory evaluation of the biscuits. The sensory evaluation was carried out in a sensory evaluation room 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) [16]. The panelists were provided with distilled water to rinse their mouths in between evaluations.

Physical evaluation of biscuits

The height, length, width, and diameter of biscuit were determined using meter rule. The biscuit weight was determined using weighing balance. The volume of biscuit was determined by seed displacement ratio as described by Akubor and Ukwuru [17]. Biscuit density was calculated as mass/volume. The spread ratio of biscuit was calculated as diameter/weight of biscuit. The break strength of biscuits was determined by subjecting the biscuit samples to various standard weights of 5, 10, and 50 kg.

Determination of phytochemical composition

The wheat, sweet orange pulp flour, and biscuit samples (control and the best samples based on the sensory evaluation) were analyzed for the phytochemical composition. The saponins, total phenol, flavonoid, and carotenoid contents were determined as described by Okwu [5]. The methods described by Onimawo and Akubor [12] were used to determine terpenoid and phytate contents.

RESULTS AND DISCUSSION

Phytochemical composition of flours

The effects of the drying methods on the phytochemical composition of sweet orange pulp flour are shown in Table 2. The total phenol content (TPC) of wheat flour was 0.01 mg/100 g. The drying method

Table 1: Phytochemical composition (mg/100 g) biscuits supplemented with sun- and oven-dried sweet orange pulp flours

Biscuit	Phenol	Saponins	Flavonoids	Carotenoids	Phytates	Terpenoids
A	0.01^{b}±0	0.3^{b}±0.2	0.4^{b}±0.1	0.20^{c}±0.2	0.81^{a}±0.4	0.23^{a}±0.1
B	0.5^{a}±0.2	0.9^{a}±0.3	1.1^{a}±0.2	3.12^{b}±0.4	0.72^{a}±0.2	0.83^{a}±0.3
C	0.4^{a}±0.1	0.8^{a}±0.5	1.3^{a}±0.1	3.49^{a}±0.3	0.93^{a}±0.1	1.04^{a}±0.1

Values are means±SD of three replications. Means within a column with the same superscript were not significantly different (p>0.05). A=100% wheat flour biscuit (control). B=Biscuit supplement with 20% sun-dried sweet range pulp flour. C=Biscuit supplemented with 20% oven-dried sweet orange pulp flour

Table 2: Phytochemical composition (mg/100 g) of sun- and oven-dried sweet orange pulp flours

Flours	Phenol	Saponins	Flavonoids	Carotenoids	Phytates	Terpenoids
A	0.1^{c}±0.1	0.2^{c}±0.2	0.3^{c}±0.2	0.40^{c}±0.4	0.8^{a}±0.1	0.02^{b}±0.2
B	0.7^{b}±0.1	0.8^{a}±0.3	0.8^{b}±0.1	4.1^{b}±0.2	0.4^{b}±0.2	0.4^{a}±0.2
C	0.9^{a}±0.2	0.6^{b}±0.1	1.1^{a}±0.1	3.9^{a}±0.1	0.3^{b}±0.1	0.1^{a}±0.3

Values are means±SD of three replications. Means within a column with the same superscript were not significantly different (p>0.05). A=100% wheat flour biscuit (control). B=Biscuit supplement with 20% sun-dried sweet range pulp flour. C=Biscuit supplemented with 20% oven-dried sweet orange pulp flour did not significantly ($p>0.05$) affect the TPC of sweet orange pulp flour. However, the oven-dried sweet orange pulp flour (0.8 mg/100 g) contained slightly higher TPC than the sun-dried sweet orange pulp flour (0.7 mg/100 g). Drying was reported to cause reduction in the phenolic content of plant foods [11]. Lim and Murtijaya [8] reported that drying could cause changes in the structure of polyphenols or cause them to adhere together with other plant components such as proteins which make their extraction using extraction methods difficult. This results in lower recoveries of polyphenols than expected. The plant cell structure may be ruptured due to thermal processing which may cause migration of phenols [8]. Various researchers have reported the breakdown of bioactive compounds during thermal processing, especially oven drying [8]. This degradation could also be attributed to the activity of degradative enzymes such as polyphenol oxidases which degrade phenolic compounds if activated by drying methods [8]. However, factors such as plant species and cell stability have been reported to influence the effect of drying on total phenolic content [8]. The loss of phenolics in the sweet orange pulp flour due to sun drying method may be attributed to enzymatic processes that occurred during sun drying [12]. Sun drying did not probably deactivate the degradative enzymes such as phenolic oxidases immediately which were able to degrade the phenolic compounds before the pulp was completely dried. Arbourne et al. [18] have reported that some phenolic compounds decompose rapidly in direct sunlight. Solar radiation was also reported to cause the degradation of phenolic compounds [18]. Oven drying at 50°C was reported to rapidly inactivate some polyphenol oxidase present in plant materials; however, some of their initial activities may have occurred earlier and caused some polyphenols to be degraded [19]. The sun drying probably could not inactivate the degradative enzymes such as polyphenol oxidase in the pulp immediately, but was able to degrade the phenols during the long time drying. The oven drying of the sweet orange pulp flour probably resulted in faster inactivation of enzymes.

The saponin contents of the sun (0.8 mg/100 g) and oven (0.6 mg/100 g) dried sweet orange flours were not significantly different ($p<0.05$). However, the sun-dried pulp flour retained higher amount of saponins than the oven-dried pulp flour. The flavonoid content of wheat flour was 0.3 mg/100 g. The flavonoid contents decreased from 1.1 mg/100 g in the oven-dried pulp flour to 0.8 mg/100 g in the sun-dried sweet orange pulp flour. The oven drying enhanced the extractability of flavonoids probably due to rupture of the cell structure which allows the exit of cellular components and access to solvent [11]. The sweet orange pulp flours contained higher amounts of carotenoids than wheat flour (0.4 mg/100 g). The drying methods significantly ($p<0.05$) decreased the carotenoid contents from 4.14 mg/100 g in the sun-dried pulp flour to 3.90 mg/100 g for the oven-dried sweet orange pulp flour. However, Onimawo and Akubor [12] reported that thermal processing increased carotenoid concentration of foods which was attributed to enzymatic degradation which weakens the protein-carotenoid aggregate. The loss of flavonoids and carotenoids with the sun drying method may have been caused by enzymatic processes that occurred during the drying. The sun drying probably did not inactivate the degradative enzymes such as polyphenol oxidases which were able to degrade the phenolic compounds during the long time drying procedure [18].

The sun-dried sweet orange pulp flour (0.3 mg/100 g) had lower amount of phytates than the oven-dried sweet orange pulp flour (0.40 mg/100 g). The phytate contents of the sweet orange pulp flours were significantly lower ($p<0.05$) than that of the wheat flour (0.8 mg/100 g). Similarly, the sun-dried sweet orange pulp flour (0.4 mg/100 g) contained higher amount of terpenoids than the oven-dried sweet orange pulp flour (0.1 mg/100 g). The terpenoids content of wheat flour was 0.02 mg/100 g.

Phytochemical composition of biscuits

The phytochemical contents of the biscuits are shown in Table 1. The phytochemical contents of all the biscuits were lower than those of the flours presented in Table 2 due to the baking temperature employed in the preparation of the biscuits. The total phenol and saponin contents of the biscuit containing sun-dried sweet orange pulp flour were higher than those of the biscuit containing oven-dried sweet orange pulp flour. However, the biscuit containing oven-dried sweet orange pulp flour had higher amounts of flavonoids, carotenoids, phytates, and terpenoids than the biscuit containing sun-dried sweet orange pulp flour. There were significant differences ($p<0.05$) between the wheat flour biscuit and the biscuits containing sweet orange flours. Phytochemical composition is reported to be influenced by type or variety of the plant, species, environmental conditions, as well as the type of soil, climate, post-harvest conditions, fertilizer applied, etc. [20]. These factors probably explain the differences in the phytochemical composition of the biscuits studied. Flavonoids have antioxidant properties that play protective role in the development of cardiovascular diseases, atherosclerosis, hypertension, ischemia/reperfusion injury, diabetes mellitus, neurodegenerative diseases (Alzheimer's disease and Parkinson's disease), rheumatoid, arthritis, and aging [4]. Two antioxidant structural features of flavonoids are the presence of beta ring catechol group and C_2-C_3 double bonds in conjugation with oxo group at C_4. The first serves to donate hydrogen/electron to stabilize radical species and the second serves to bind transition metal ions such as iron and copper [12]. The high content of carotenoids in the biscuits containing sweet orange pulp flours suggests that consumption of the biscuits could provide some health benefits. Carotenoids are powerful antioxidants which protect the cell by reacting with oxidizing factors and neutralizing their effects [12]. Carotenoids are effective in preventing cancer and other degenerative diseases [4]. Phenols such as tannins form insoluble complexes with proteins and reduce their digestibility and palatability when present in foods in high amount [21]. However, moderate levels of polyphenols play a significant role in human nutrition. Phenolic compounds possess significant antioxidant activity (due to their ability to adsorb, neutralize, and quench free radicals [22]). Their ability as free radical scavenger is attributed to their redox properties, the presence of conjugated ring structures, and carboxylic group which are reported to inhibit lipid peroxidation [22]. Tannins hasten the healing of wounds and inflamed mucus membrane [23]. The binding of iron by tannins and phytate prevents them from generating free radicals and thus has protective effect against cancer [23]. The levels of saponins in the biscuits containing sweet orange pulp flours (0.8–0.9 mg/100 g) were higher than that of wheat flour biscuit (0.3 mg/100 g). Saponins possess health benefits which include antioxidative, anti-inflammatory, anti-apoptosis, and immune-stimulant properties [22]. Saponins inhibit growth of cancer cells and help to lower blood cholesterol [12]. They reduce uptake of glucose and cholesterol through intraluminal physicochemical interaction during food transition in the gut. This confers chemoprotection against heart diseases [23]. Hence, saponins are useful in the treatment of cardiovascular disease and other health problems [8]. The cholesterol-lowering mechanism of saponins is that it binds cholesterol in the intestinal lumen, making it less readily reabsorbed. Saponins may also bind bile acid, causing reduction in its enterohepatic circulation and increasing its fecal extraction [8]. When there is increased bile acid excretion, synthesis of cholesterol in the liver is enhanced, thus, lowering plasma cholesterol [23]. Saponins boost energy and serve as natural antibiotics [5]. Humans, generally, do not suffer severe poisoning from saponins [5].

The phytate contents of the biscuits containing sun (0.76 mg/100 g) and oven (0.93 mg/100 g) sweet orange pulp flours were not significantly different ($p>0.05$). The phytates content of wheat flour biscuit was 0.81 mg/100 g. Phytates are considered anti-nutrients when available in large quantity (>3 g/100 g) by virtue of their ability to chelate divalent metals and prevent their absorption [23]. The structure of phytate has high density of negatively charged phosphate groups which can complex many mineral ions [4]. The complex ions are not available for intestinal absorption [4]. Phytates have also been implicated in decreasing protein digestibility by forming complexes and also by interacting with enzymes such as trypsin and pepsin [23]. However, at low levels in the products investigated in the present study, phytates have anticancer and antioxidant activity [20]. It forms iron chelate that

Table 3: Physical properties of biscuits supplemented with sun- and oven-dried sweet orange pulp flours

Biscuit	Diameter (cm)	Height (cm)	Spread ratio	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Break strength (kg)
A	5.3^a±0.6	0.8^a±0.0	6.4^b±0.1	18.7^a±0.1	0.2^a±0.3	81.3^a±0.3	7.5^b±0.1
B	5.3^a±0.1	0.7^b±0.1	7.7^a±0.3	16.9^b±0.1	0.2^a±0.2	76.8^b±0.1	6.4^c±0.3
C	5.2^a±0.2	0.7^b±0.2	7.5^a±0.2	16.6^b±0.2	0.2^a±0.1	69.2^c±0.2	8.0^a±0.1

Means within a column with the same superscript were not significantly different (p>0.05). A=100% wheat flour biscuit (control). B=Biscuit supplement with 20% sun-dried sweet range pulp flour. C=Biscuit supplemented with 20% oven-dried sweet orange pulp flour

Table 4: Sensory properties of biscuits supplemented with sun- and oven-dried sweet orange pulp flours

Biscuit	Color	Flavor	Taste	Texture	Overall acceptability
A	8.05^a	7.90^a	7.90^a	7.80^a	8.15^a
B	6.90^b	7.10^a	6.50b	7.30^a	7.15^b
C	6.95^b	7.15^a	7.05^a	7.15^a	7.30^b

Means within a column with the same superscript were not significantly different (p>0.05). A=100% wheat flour biscuit (control). B=Biscuit supplement with 20% sun-dried sweet range pulp flour. C=Biscuit supplemented with 20% oven-dried sweet orange pulp flour

suppresses lipid oxidation by blocking iron driven hydroxyl radical generation [20]. The terpenoid contents of the wheat flour biscuit were 0.23 mg/100 g. The oven drying increased the terpenoids content from 0.83 mg/100 g in the sun-dried pulp to 1.04 mg/100 g in the oven-dried sweet orange pulp flour.

Physical properties of biscuits

The physical properties of the biscuits are shown in Table 3. The diameters of the biscuits were not significantly different (p>0.05). However, 100% wheat flour biscuit had higher height (0.83 cm) than the biscuits containing sun (0.7 cm) and oven (0.70 cm) dried sweet orange pulp flours. The incorporation of sweet orange pulp flours diluted the proteins of the biscuits from the flour blends. This probably affected the formation of three dimensional networks by the gluten which did not enhance gas retention by the dough. This probably reduced the height of the biscuits containing sweet orange pulp flours. Gluten network developed during kneading of the dough has gas retention property. The gas aerates the dough and improves loaf height and volume. The property was reduced due to the addition of oven/sun-dried sweet orange pulp flour to wheat flour.

The biscuits containing sweet orange pulp flours had significantly higher spread ratio than 100% WF biscuit. The spread ratio increased from 6.42 for 100%WF biscuit to 7.50 and 7.72 for the biscuits containing sun- and oven-dried sweet orange flours, respectively. Dayakar *et al.* [24] reported that biscuit spread is affected by competition of ingredients for available water. Akubor [15] suggested that spread ratio is affected by the water absorption capacity of the ingredients. Flour or any other ingredient which absorbs water during dough mixing will reduce biscuit spread. The previous studies have reported that wheat flour has higher water absorption capacity than sweet orange pulp flour [15]. This probably explains the low spread of 100% wheat flour biscuit. However, it appears other functional properties affect spread of biscuits. Akubor [15] reported that spread factor of biscuit is affected by dough viscosity as well as the acid-base reaction of the ingredients (sodium bicarbonate and fat) which causes bubbles in the dough to expand in volume. Diameter and spread ration of biscuits are important parameters used for the evaluation of wheat varieties for biscuit making [14]. Large biscuit diameter and high spread ratio are considered as desirable quality attributes [13].

The weight of 100% WF biscuit (18.7 g) was higher than those of 16.6 and 16.9 g for the biscuit containing oven- and sun-dried sweet orange pulp flours, respectively. Shittu et al. [25] documented that the basic determinant of weight of baked products to be the quantity of dough baked and the amount of moisture and carbon dioxide that diffused out of the product during baking. The wheat flour and the pulp flours absorbed water but during baking, the sweet orange pulp flours lost water more readily than the wheat flour. There was no significant difference in the volume of the biscuits. However, the biscuit containing oven-dried sweet orange pulp flour occupied more volume that the other biscuits. The oven drying probably modified the protein and carbohydrate in the sweet orange pulp flour. The modified constituents may have enhanced gas retention by the dough. Volume of biscuit is of great importance in determining quality because it is generally influenced by the quality of the ingredients used in the formulation of the biscuits [17]. However, the biscuits containing oven-dried sweet orange pulp flour had higher break strength than the other biscuits. About 100% wheat flour biscuit (81.3 g/cm^3) was denser than the biscuits containing sun (76.8 g/cm^3) than oven (69.7 g/cm^3) dried sweet orange pulp flours. The relationship between the spreadability, height (thickness), and the break strength of biscuit has been previously reported [13]. The thinner the biscuit, the lesser the ability to withstand stress/load. Thus, the level of supplementation affected the ability of the biscuits to withstand stress. The break strength reduced with the increase in the level of sun- and oven-dried orange pulp flour in biscuit samples.

Sensory properties of biscuits

The sensory properties of biscuits supplemented with sun- and oven-dried sweet orange pulp flours are shown in Table 4. About 100% wheat flour biscuit was rated higher than the other biscuits in all the sensory attributes evaluated probably because wheat flour is conventionally used to prepare biscuits. The scores for the color of the biscuits containing sun- and oven-dried sweet orange pulp flours were not significantly different (p>0.05). The low scores for the color of the sweet orange based biscuits may have been contributed by the phytochemicals in the sweet orange pulp flour which would, however, potentially increase the health benefit of the biscuit. The sweet orange pulp flours probably provided additional reducing sugar for Maillard browning to take place [12]. Thus, the biscuits containing sweet orange pulp flours were darker than the biscuit that did not contain the pulp flour. The scores for flavor of the biscuits containing sun- and oven-dried sweet orange pulp flours were not significantly different (p>0.05). However, the biscuit containing oven-dried sweet orange pulp flour was rated slightly higher than that containing sun-dried pulp flour. The oven drying may have caused Maillard reactions in the sweet orange pulp which probably generated flavor that enhanced the acceptance of the biscuit containing oven-dried sweet orange pulp flour. The panelists probably noted the sweet orange flavor in the biscuits containing the pulp flours and this as well as the array of phytochemicals in the pulp may explain the low appreciation of the biscuits for flavor relative to the control. About 100% wheat flour biscuit received higher score for texture than the biscuits containing sweet orange pulp flours. However, the scores for the texture of the biscuits containing sweet orange pulp flours were not significantly different (p>0.05). The incorporation of sweet orange pulp flours into the biscuits reduced the gluten proteins which are responsible for the structure of baked products. This probably interfered with the development of gluten complex. Structural modification of the starch and protein constituents of the flour blends might have occurred due to the blending, which probably did not enhance gas retention ability of the gluten network which helps to modify the texture of baked foods. Sun and oven drying of sweet orange pulp did not significantly (p>0.05) affect the overall acceptability of the biscuits supplemented with the pulp flours. However, the biscuit containing oven-dried sweet orange pulp flour was rated slightly higher than that containing sun-dried sweet orange pulp flour for overall acceptability. Indeed, the biscuit containing oven-dried sweet orange pulp flour was rated higher in all the sensory attributes assessed except texture.

CONCLUSION

Based on the results of this study, it may be concluded that the biscuits supplemented with sun-dried sweet orange pulp flour contained higher amounts of phenol, saponins, and phytates but lower amounts of carotenoids and terpenoids than the biscuits supplemented with oven-dried sweet orange pulp flour.

The diameter, height, weight, volume, and spread ratio of the biscuits supplemented with sun- and oven-dried sweet orange pulp flours were not significantly different.

Biscuits supplemented with sun- and oven-dried of sweet orange pulp flours were not significantly different in their sensory properties. However, the biscuit containing oven-dried sweet orange pulp flour was rated higher in all the sensory attributes except texture.

RECOMMENDATION

Based on the results of the present study, it is recommended that:

1. It is recommended that sweet orange pulp should be sun dried and oven dried at 60°C for the preparation of flour for the supplementation of wheat flour in biscuits
2. The antioxidant activity and storage stability of biscuits supplemented with sun- and oven-dried sweet orange pulp flours should be assessed
3. The performance of sun- and oven-dried sweet orange pulp flours in other food systems should be evaluated.

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