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Research article

Physicochemical and rheological study of orange pulp fortified cookies

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Abstract
This study was aimed to find out the effects of supplementation of wheat cookies with orange pulp fiber at 0%. 3%, 6%, 9% levels. The orange pulp fiber used was contained of protein 7.40%, fat 2.19%, moisture 8.10%, fiber 7.31%, ash 2.55%, water holding capacity 4.71%, oil holding capacity 1.91% and pH 3.81. The rheological analysis showed that with the addition of orange pulp fiber, water absorption and mixing tolerance index were increased while dough development time and dough stability were decreased among the treatments. Variance analysis of the formulations used for making cookies showed significant differences ($P \leq 0.05$) for appearance, flavor, texture, and overall acceptance. So it can be concluded that orange pulp fiber may be used as a food additives to gain nutritional and health benefits.
Keywords: Supplementation, orange pulp fiber, water holding capacity, oil holding capacity, rheological, sensory characteristics

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Introduction

Citrus is the most abundant crop in the world with worldwide production of over 88·1 tons and one-third of the crop is processed [1]. Oranges, lemons, grapefruits and mandarins represent approximately 98% of the entire industrialized crop, oranges being the most relevant with approximately 82% of the total [2]. Oranges are mainly processed to obtain juice. They are also used to produce jams and marmalade [3]. Approximately 50% of the orange fruit is juice, while other 50% is the rind, albedo, sacs and seeds, which contain varying amount of water, soluble sugars, fiber, organic acids, amino acids, proteins, minerals, oils and lipids, and also contains flavonoids and vitamins. All of these components are found in different amounts depending on the fraction of the fruit (juice, albedo, flavedo, rag, pulp, and seeds) and therefore, their proportion in citrus juice residues depends on the juice extraction system used [4-6].

Worldwide industrial citrus waste was estimated more than 15.1 tons, as the amount of residue obtained from the fruits accounts for 50% of the original whole fruit mass [7]. Citrus wastes constitute a severe environmental problem [1, 8]. They consist of peels (albedo and flavedo), which are almost one-fourth of the whole fruit mass and seeds and fruit pulp, which are the remaining of juice and essential oil extraction [9]. While fiber content in citrus is almost 25-70% [10]. The fruits and their by-products can be dried for preservation and further use, which enables the use of features of interest, like low fat and digestible carbohydrates, high fiber and low calorie content [11]. Thus, one important source of citrus dietary fiber is the residue from the orange juice industry. Fiber from citrus can be obtained from the edible parts [12, 13] and attracts, binds, and manages high levels of water (up to 12 times of its weight) in baked goods, meat and poultry products, and sauces. Additionally, citrus peel is a rich source of fiber and antioxidants, but the higher levels of astringent compounds make it unsuitable for human consumption [14].

The roles of fiber and phytochemicals in sustaining good health cannot be over-emphasized. The benefits of fiber in diets include promotion of digestive health and weight loss, control of blood sugar levels and prevention of Type 2 diabetes. Other benefits include lowering cholesterol, indirectly preventing heart disease and stroke [15]. Phytochemicals are non-nutritive plant chemicals that have either protective or disease protective properties. Dietary intake of phytochemicals may promote health benefits by protecting against chronic degenerative disorders, such as cancer, cardiovascular and neurodegenerative diseases [16, 17]. Due to the immense benefits of orange peel, it was planned to use in cookies. This study was designed to evaluate the chemical composition, water and oil holding capacity of orange peel and the effect of their incorporation at different levels (0-9%) on the chemical, physical, farinograph properties and sensory evaluation of cookies.

Materials and Methods

Procurement of raw material

Freshly sweet oranges were procured from Citrus Research Center, Sargodha, Pakistan and other materials were purchased from the local market.

Preparation of orange pulp powder

Citrus pulp powder was prepared according to the method reported by Fernandez-Lopez et al. [17]. Oranges were washed with warm water to remove possible pathogenic microorganisms (vegetative cells). Afterwards, oranges were pressed using a helical press to remove excess liquid prior to drying. Drying was carried out in an oven at 50°C for 24 h. A grinder mill and sieves were used to obtain a powder with the particle size of less than 0.2mm.

Characterization of orange pulp powder

The orange pulp powder was analyzed for moisture, crude protein, fat, crude fiber, ash, water holding capacity, oil holding capacity and pH. Proximate composition was determined by [18]. Moisture (%) was determined by drying a 3g sample at 105°C to constant weight. Ashing (%) was performed at 550°C for 5h. Protein (%) was analyzed according to the Kjeldahl method. Factor 6.25 was used for the conversion of nitrogen to crude protein. Fat (%) was calculated by weight loss after a 6-cycle extraction with petroleum ether in a Sohxlet apparatus. The crude fiber content was estimated by digesting the fat free samples of the orange pulp in 1.25% H_2SO_4 followed by 1.25% NaOH solution. Water-holding capacity (WHC) and oil- holding capacity (OHC) of orange pulp powder were analyzed according to the method of Robertson and Eastwood [19] by using a simple filtration vacuum suction system. Experimental conditions were as follows: particle diameter <0.2 mm; filter of 40 µm; vacuum pressure of 70 mm Hg; filtration time of 15 min, and temperature of 30°C. Experimental conditions for oil- holding capacity (OHC) were as follows: particle diameter <0.2 mm; filter of 40 µm, vacuum pressure of 70 mm Hg, filtration time of 15 min, and temperature of 30°C.

Development of cookies

Cookies were prepared in Cereal Research Institute, Ayub Agriculture Faisalabad, Pakistan according to Approved Methods of American Association of Cereal Chemists (AACC) [20], method no. 10-50D with some modifications. The orange pulp powder was added at the rate of 0, 3, 6 and 9% along with other ingredients as described in Table 1.

Table 1 Ingredients for cookies production.

Ingredients	Quantity
Flour	500g
Sugar	250g
Shortening	250g
Egg	2
Sodium Bicarbonate	8g

Proximate composition of fortified cookies

Proximate composition of orange pulp powder fortified cookies was analyzed for moisture content by AACC method no. 44-15A, for crude protein by method no. 46-30, for crude fat by method no. 30-25, for crude fiber method no. 32-10 and for Ash by method no. 08-01 [20].

Farinographic studies of orange pulp powder fortified flour

Rheological characteristics such as water absorption, dough stability, dough development time, arrival time and departure time of the composite flours were measured using the Brabender farinograph (CW Brabender, Duisburg, Germany) according to the standard method no. 54-21 of AACC [20]. The instrument automatically determined the amount of flour to be poured into the mixer of the farinograph based on the moisture content of the flour samples. The farinograph was equipped with a 300 g capacity mixer. Mixing was carried out for 20 minutes. Immediately after the mixing was started, the computer automatically started to plot the graph.

Sensory evaluation of cookies

The subjective evaluation of cookies was carried out for the external sensory characteristics. Cookies were evaluated for color, appearance, flavor, taste, crisp and overall acceptability. Judgments were made through rating products on a 9 point Hedonic Scale with corresponding descriptive terms ranging from 9 'like extremely' to 1 'dislike extremely' according to the method described by Larreaa et al. [21] to find out the most suitable treatment for cookies production.

Statistical analysis

Statistical analyses were performed by using Minitab statistical software version 16 (Minitab Inc., State College, PA, USA) and by using two way analyses of variance (ANOVA) and LSD multiple comparison test.

Results and Discussion

Characterization of orange pulp

The results of chemical analysis of orange pulp fiber, including moisture, crude protein, crude fat, crude fiber and ash content, WHC, OHC and pH are presented in Table 2. Larreaa et al. [22] also reported similar composition of orange pulp. Eaks and Sinclair [23] described that protein, ash, and lipid contents were lower in mature oranges than in green oranges.

Table 2 Chemical composition of orange pulp fiber.

Parameters	Mean (%)
Protein	7.40±0.16
Fat	2.19±0.08
Moisture	8.10±0.14
Crude fiber	7.31±0.10
Ash	2.55±0.04
Water holding capacity	4.71±0.08
Oil holding capacity	1.91±0.13
pH	3.81±0.46

Effect of Orange pulp on proximate composition of cookies

Proximate composition of cookies is presented in Table 3. The analysis of variance for treatments indicated that moisture, ash, protein, crude fiber, crude fat content were found significantly different among all treatments. Maximum moisture content was observed in treatment T1 (4.7%) while treatment T3 (3.8%) showed minimum moisture content. Labuza and Hyman [24] reported that development of food products with low moisture content is important to achieve increased shelf life. Minimum protein content was observed in treatment T4 (4.4%) while maximum in treatment T1 (6.7%). Maximum crude fat was observed in treatment T1 (20.4%). Ash and crude fiber were observed maximum in treatment T4 2.8% and 4.11%, respectively. Dietary fiber has been reported to increase the nutritional value of bread, but at the same time it usually alters the rheological properties of the dough and thus the quality and sensory properties of the bread [25].

Table 3 Effect of orange pulp fiber on proximate composition of cookies (DW).

Treatments	Moisture (%)	Protein (%)	Fat (%)	Ash (%)	Crude fiber (%)
T1	4.71a	6.70a	20.4a	1.9d	0.89d
T2	4.49b	5.87b	17.7b	2.3b	2.79c
T3	3.81d	5.22c	17.3c	2.1c	3.45b
T4	4.30c	4.40d	16.9d	2.8a	4.11a

T1 (0% orange fiber), T2 (3% orange fiber), T3 (6% orange fiber), T4 (9% orange fiber), DW= dry weight)

Effect of orange pulp on rheological character of dough

Mean values of Rheological character of orange pulp flour are presented in Table 4. It is confirmed from the analysis of variance for farinographic studies that water absorption, dough development time, dough stability and mixing tolerance index differed significantly among different treatments. The results showed that with the addition of fiber, water absorption and mixing tolerance index was increased among the treatments while dough development time and dough stability were decreased among the treatments. The results are in line with the study of Larreaa et al. [22]. Dietary fiber may interact with water by means of polar and hydrophobic interactions, hydrogen bonding, and enclosure. The results of these interactions vary with the flexibility of the fiber surface. When the fiber is insoluble or junction zones are formed, this might result in profound changes in the surrounding water. Such interactions are capable of affecting the structure and salvation properties of water far removed from the intermediate surfaces involved. Unfermented dietary fiber has a tendency to form low-density expanded water that acts as a preferential solvent for hydrophobic molecules when compared to the less-structured denser water within the much more hydrophilic mucus layer [26].

Effect of orange pulp fiber on sensory characteristics of cookies

Mean values of sensory scores of orange pulp fiber fortified cookies are exhibited in Table 5. Variance analysis of the formulations used for making biscuit-type cookies showed significant differences ($P \leq 0:05$) for appearance, flavor, texture, and overall acceptance. The cookies with 3% and 6% orange pulp had the highest levels of acceptance for appearance. Maximum flavor was observed in T3 (7.2) while T4 (5.50) gave least value for flavor. With the increase of orange fiber, texture of the cookies was become hard and acceptability level was

Table 4 Effect of orange pulp fiber on the rheological characteristics of dough (DW).

Treatments	Water absorption (%)	Dough development time (min)	Dough stability (min)	Mixing tolerance index (BU)
T1	59.560D	7.2A	11.20A	40D
T2	61.0C	6.50B	7.20B	55C
T3	65.50B	6.30B	5.80C	65B
T4	69.0A	6.20B	4.60D	80A

T1 (0% orange fiber), T2 (3% orange fiber), T3 (6% orange fiber), T4 (9% orange fiber), DW= dry weight) decreased. However, there were no significant difference between control and orange fiber cookies up to 6% orange fiber. In a previous report, biscuits prepared with aqueous extracted wheat bran at 6% substitution level produced biscuits close to the control in color, flavor, texture and overall acceptability [27].

Table 5 Sensory evaluation of cookies after the addition of orange pulp fiber.

Formulation	Appearance	Flavor	Texture	Overall acceptance
T1	6.55b	6.52a	7.46a	6.84a
T2	6.90b	7.03a	7.70a	7.21a
T3	7.16a	7.20a	6.74a	7.03a
T4	7.00a	5.50b	4.00b	5.50b

Conclusions

This study investigated the potentials of orange pulp fiber in cookie production. The use of orange pulp fiber in cookies has the advantage of improving the fiber, ash and phytochemical levels in cookies. However, only cookies produced with 6% orange pulp fiber had acceptable sensory quality. With increasing levels of orange pulp fiber, the sensory characteristics of cookies were affected badly. The results indicate that orange pulp fiber a by-product from orange processing, could be considered as an alternative dietary fiber for cookies and other bakery products

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