Development of a functional sponge cake using oat fiber

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***Abstract*—This article evaluates the effect of oat fiber as a functional ingredient in cake production. In this research wheat flour was replaced (0, 5, 10, 15, 20 and 30%) with the oat fiber and the prepared cakes were evaluated for its physical and sensorial properties. The results showed that with increasing the Oat fiber level, batter density of the cakes increased significantly. Result of textural tests (TPA test) showed that Fiber increased the crumb hardness and decreased cohesiveness of cake. Cakes also were evaluated for flavor, texture and taste by a descriptive sensory panel. Based on overall liking (5-point Hedonic scale), evaluation of cakes showed that 20% addition of Oat fiber had higher overall acceptability.**

Keywords- Oat fiber, Batter, Sponge cake, Functional cake

I. INTRODUCTION

Oat (*Avenal sativa* L.) is principally a cool season crop and is mainly used as an animal feed. Nevertheless, the attractiveness of oat as a part of human diet as food or industrial raw material has increased in recent years because of reports indicating the nutritional characteristics of oat β-glucan as a functional ingredient. In addition to β-glucan, oat contains other dietary fibers, vitamins, minerals, antioxidants, sterols, and other bioactive compounds, proteins of high lysine content and oil of favorable ratio of polyunsaturated to saturated lipid. These compounds can help prevention of some serious diseases such as some cancers, cardiovascular problems, high serum cholesterol level and heart disease. Accordingly, the Food and Drug Administration (FDA, 2001), has allowed health claims for foods that contain more than 0.75 g of oat-derived β-glucan for each serving portion. Regarding the nutritional value and health benefits of oat, the effects of inclusion of oat derived materials (e.g. oat flour and fiber) on the quality of some food products (e.g. noodles, bread, and biscuits) have been studies (_Sudha et al. 2007; Majzoobi et al. 2013). Only a few studies were conducted to show the effects of oat fiber on the quality of cakes. Recently, oat fiber (up to 20%) and oat bran (30%) treated with endoxylanase enzyme have has been used as a source of dietary fiber in production of ordinary cakes (Gomez et al. 2010). The results of this studies showed that addition of oat bran level had undesirable effects on the cake color, texture and taste. To the best of our knowledge addition of oat fiber as a source of insoluble dietary fiber to the cakes have not been examined. Therefore, the main aim of this study was to develop functional cake containing oat fiber and to determine the subsequent changes in the batter and cake quality.

II. MATERIALS AND METHODS

A. Materials

Wheat flour, white fine sugar, low fat milk, sunflower oil, baking powder, vanilla and fresh whole eggs were locally purchased. Wheat flour contained 11.32 ± 0.23% moisture, 9.53 ± 0.30% protein, 0.38 ±0.20% fat, 0.50 ± 0.10% ash as determined by the Approved Methods of the AACC (2000) methods. Oat fiber was gifted by Karen Nutrilife Co., Tehran, Iran. Other chemicals used in the analysis of cake were of analytical grade and were purchased from Merck, Darmstadt, Germany.

B. Methods

Cakes were prepared according to the following recipe: 100g cake flour, 75g sugar, 56 g whole fresh eggs, 31.25g oil, 62.5g low fat milk, 3.2g baking powder and 0.45g vanilla. For oat fiber enriched cakes, different amounts of the flour (0, 5, 10, 15, 20 and 30%, w/w) was replaced by oat fiber.

1) Batter preparation

Whole egg and vanilla were whipped well with sugar in a mixer (Kitchen–Moulinex mixer, Model HM 1010, Beijing, China) at medium speed, for 2 minutes then milk was added and mixed for 2 minutes to obtain a thick cream. Afterward, cake flour mixed well with baking powder was added gradually. Finally, the sunflower oil was added to the recipe and gently mixed to obtain cake batter.

2) Determination of the batter density

The weight of a glass-tube filled with the batter was divided by the weight of the same tube filled with distilled water (Majzoobi *et al.* 2012).

3) Determination of the batter Bostwick number

The Bostwick number of the batter was determined using a Bostwick consistometer at ambient temperature (20±0.5ºC). The distance moved by the batter (100 g) for 30 s was determined as Bostwick number which has negative correlation with batter consistency (Baeva *et al.* 2000).

4) Cake preparation

Cake batter (250 g) was transferred into rectangular Teflon pan (95 mm width, 175 mm length, 50 mm height) and baked in an electric oven (Nanerazavi Industrial. Iran) at 180˚C until a gold crust was formed. After baking, the pans were left at room temperature for 1 h to cool down and then the cakes were removed from the pans. Then, they were wrapped in polyethylene wraps, coded and sealed to avoid drying. These samples were stored at 25 ˚C for further experiments.

5) Determination of cake height and volume

The height of the cakes was measured using a digital caliper and the cake volume was determined using the rapeseed displacement method as described by the Approved Methods of the AACC (2000) (No.10-10-B).

6) Color evaluation

The color of cake crust and crumb were determinate using a digital camera (Canon, Model IXUS 230 HS, 14.0 Megapixels, Japan) and Adobe Photoshop 11 as described by Yam, and Papadakis (2004). To take pictures resolution, contrast and lightness of all images were set to 300 dots per inch (dpi), 62 (%) and 62 (%), respectively. The lightness (L-value), redness-greenness (a) and blueness-yellowness (b) values were measured for the samples.

7) Determination of the textural properties of the cakes

To determine the textural properties of the cakes, first the crust was removed and cubic pieces of the cakes (30 × 30 × 30 mm) were cut using a sharp knife. Textural properties of cake crumb were measured suing a TA-XT2 texture analyser (Stable Microsystems Ltd, Surrey, UK) provided with the software Texture Expert. A metallic cylindrical probe with diameter of 80 mm was used in a Texture Profile Analysis (TPA) double compression test. Then the crumb was compressed to 25% of its initial height, at pretest speed of 5 mm s^{-1}, test speed of 0.25 mm s^{-1}, with a 10 s delay between first and second compression. From the TPA profile the peak force of first compression cycle, cake hardness, cohesiveness, springiness, gumminess and chewiness were determined as described by Majzoobi et al. (2012).

8) Sensory evaluation

Cakes were evaluated for their organoleptic characteristics by performing a five-point hedonic test using 12 semi-trained panelists (6 females and 6 males, age between 20-40). Samples were coded with three random digits and placed in disposable colorless plates and presented to the panelists. The panelists were asked to evaluate the samples and score them between 1 (most disliked) to 5 (most liked).

9) Statistical analysis

The tests were performed at least in triplicates. Values reported in figures and tables are the average of triplicates ± standard deviation. A completely randomized design was utilized to determine significant differences among samples from analysis of variance (ANOVA). Duncan's multiple range test ($p<0.05$) was used to determine the significances within treatments using statistical software of Statistical Package for Social Science 16 (SPSS) (SPSS, Inc., New Jersey, USA).

III. Results and discussion

- **Effect of oat fiber on batter properties**

Batter consistency is related to its capacity to retain air during mixing or the CO_2 produced from baking powder while batter density correlates with the air quantity in the batter (Gómez *et al.* 2007). Based on the results (Figure 1) increasing the oat fiber content, increased batter consistency and hence the Bostwick number decreased from 8.60 to 4.93 cm. Similarly, Rosell et al., (2009) and Gomez et al. (2010) reported that the addition of insoluble fibers increased cake batter density. The increase in the batter consistency is related to the high water absorption of the oat fiber. The increase in batter consistency is also related to the increase in batter density. As Figure 1 shows, increasing the oat fiber level increased batter density from 1.02 to 1.21 (g/cm^3) (Figure 1). These changes in batter density and consistency may result in further changes in cake volume and texture.

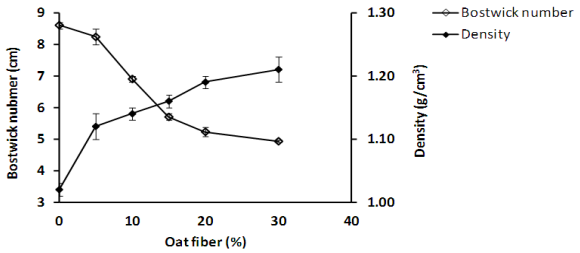

Figure 1. Bostwick number and density of the cake batter containing different levels of oat fiber.

Table1. Effect of different content of oat fiber on cake density, height and volume*.

Oat fiber (%)	Cake height (cm)	Cake density (g/cm^3)	Cake volume (cm^3)
0	4.72±0.02^d	0.405±0.001^a	541.18±0.77^e
5	5.00±0.20^c	0.403±0.003^a	542.68±0.23^e
10	5.15±0.10^c	0.400±0.001^a	545.57±0.00^d
15	5.20±0.10^c	0.399±0.003^a	547.25±0.01^c
20	5.50±0.10^b	0.394±0.002^b	565.97±0.01^b
30	6.20±0.10^a	0.357±0.003^c	586.84±0.00^a

*Values followed by different letters in the same column are significantly different (P<0.05).

Effect of oat fiber on cake properties

Different levels of oat fiber had significant effect on cake height, density and volume (Table 1). The highest cake height was 6.20 cm that obtained at 30% oat fiber, while the lowest height was 4.72 cm that obtained for the control sample. The density of the cakes decreased from 0.405 to 0.357 (g/cm^3) as the level of the oat fiber increased from 0 to 30%. Opposite trend was observed for the cake volume. So that the highest volume (586.84 cm^3) was obtained for the sample containing 30% oat fiber while the lowest volume was obtained for the samples containing 0 and 5% oat fiber (about 541.18 cm^3).

Effect of oat fiber concentration on cake physical properties

The physical properties of the cakes are of interest as they are related with consumer acceptance. The effect of fiber on the quality properties of cake is shown in Table 2. The hardness and gumminess of the cakes increased as the level of oat fiber increased. However, a decrease in the cohesiveness, springiness and chewiness of the cakes were observed with increasing the percentage of the oat fiber.

Table2. Effect of different content of oat fiber on textural properties of the cake.

Oat fiber (%)	Hardness (Kg)	Cohesiveness	Springiness	Gumminess (Kg)	Chewiness (Kg)
0	0.430±0.002^f	0.860±0.010^a	0.958±0.002^a	0.370±0.006^f	0.305±0.009^a
5	0.472±0.003^e	0.773±0.002^b	0.913±0.002^b	0.365±0.002^e	0.258±0.003^b
10	0.578±0.002^d	0.730±0.002^c	0.887±0.002^c	0.423±0.003^d	0.274±0.003^c
15	0.633±0.002^c	0.716±0.002^d	0.876±0.001^d	0.454±0.001^c	0.284±0.000^d
20	0.679±0.002^b	0.707±0.002^e	0.865±0.002^e	0.480±0.002^b	0.294±0.002^e
30	0.707±0.002^a	0.665±0.002^f	0.859±0.002^f	0.471±0.002^a	0.268±0.002^f

Mean values ± standard deviation; Values followed by different letters in the same column are significantly different (P<0.05).

Effect of oat fiber concentration on color characteristics of cakes

As can be seen in Table3 and 4 crust color became darker (lower L* values), lower reddish (lower a* values) and more yellowish (higher b* values) when fiber was added. Crust color is affected by Maillard reactions. Since the presence of fiber does not modify the quantity of sugars and amino acids, although lower proportion of flour is used in the formulation, it was possible that color changes were due to changes in pH (fiber could act as a buffer) and changes in water availability to give those reactions . Crumb color depends to a high extent on raw materials since the increase in temperature is not high enough to give Maillard or caramelization reactions. It was observed that when the percentage was increased, L* value decreased.

Table3. Effect of different content of oat fiber on crumb color.

Oat fiber (%)	Crumb (L)	Crumb (a)	Crumb (b)
0	79.3±1.5^a	-7.7±1.2^a	42.3±0.6b^d
5	75.0±1.0^b	-8.0±0.0c^b	43.0±1.0^c
10	69.0±1.0^c	-10.0±1.0^c	44.6±0.5^c
15	63.0±1.0^d	-12.0±1.0^d	45.4±0.3^c
20	62.0±1.0^{da}	-12.7±1.5^d	46.7±0.3^b
30	61.0±1.0^e	-13.0±1.0^d	47.3±0.2^a

Mean values ± standard deviation; Values followed by different letters in the same column are significantly different (P<0.05).

Table4. Effect of different content of oat fiber on crust color.

Oat fiber (%)	Crust (L)	Crust (a)	Crust (b)
0	40.3 ± 0.6^{a}	8.7 ± 0.6^{a}	26.7 ± 2.1^{b}
5	38.3 ± 0.6^{b}	7.0 ± 1.0^{b}	27.0 ± 1.0^{b}
10	36.0 ± 1.0^{c}	5.3 ± 1.5^{c}	28.3 ± 1.5^{b}
15	35.0 ± 1.0^{bc}	3.0 ± 1.0^{d}	28.7 ± 0.6^{b}
20	33.7 ± 0.6^{d}	1.0 ± 1.0^{e}	29.0 ± 1.0^{ab}
30	30.0 ± 1.0^{e}	-1.0 ± 1.0^{f}	30.7 ± 1.5^{a}

Mean values ± standard deviation; Values followed by different letters in the same column are significantly different ($P<0.05$).

Sensory evaluation

Sensory evaluation data of the cakes studied are presented in Table 5 and Figure 3. These valuations could be related to mouthfeel sensation. Regarding the overall acceptability, it can be stated that addition of 20% oat fiber led to cakes with a greatest appreciation by panelists. This is mainly attributed to the textural parameters, the appearance and taste of the respective cakes. Therefore, the replacement (20%) of wheat flour by oat fiber reduced the energy provided by these cakes, due to low available carbohydrate and proteins, besides utilizing it's healthy benefits.

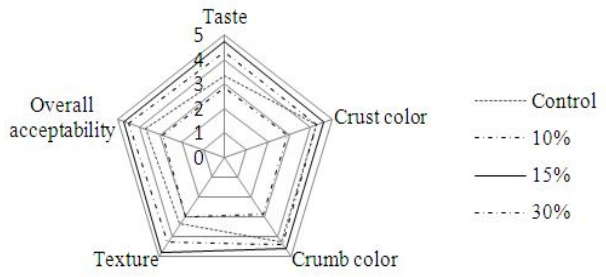

Fig2. Effect of oat fiber level on sensory evaluation

Conclusions

Overall results showed that it is possible to obtain cakes with very similar physical and sensory characteristics to the control when flour was substituted by fiber in quantities close 20%. It is remarkable the high acceptability scores obtained in the fiber enriched cakes. However, it is essential an adequate selection of fiber, since fiber size affected above all batter rheology and cake consumer acceptability.

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