

## Effects of Commercial Oat Fiber on Characteristics of Batter and Sponge Cake

M. Majzoobi<sup>1\*</sup>, M. Habibi<sup>1</sup>, S. Hedayati<sup>1</sup>, F. Ghiasi<sup>1</sup>, and A. Farahnaky<sup>1</sup>

### ABSTRACT

Despite the numerous health effects of the dietary fibers, the amount of the fiber in the diet is generally lower than the recommended value. Therefore, increasing the fiber content of the foods particularly those of high consumption can compensate for the shortage of the fiber in the diet. However, it seems a difficult task since increasing the fiber content can have adverse effects on product acceptability. The main objective of this study was to include oat fiber in the cake recipe and to determine the physical and sensory properties of the resultant product. Therefore, oat fiber at different levels of 0, 5, 10, 15, 20, and 30% (w/w, flour basis) were added in the cake recipe. Increasing the level of oat fiber resulted in the increase in batter density and consistency and cake volume. In addition, cake crust and crumb became darker. Cake hardness and gumminess increased, while cohesiveness and springiness decreased as determined using a texture analyzer. Cakes containing no more than 20% oat fiber had acceptable sensory characteristics. In total, it was concluded that addition of maximum 20% oat fiber to cake can result in a product of acceptable sensory characteristics.

**Keywords,** Dietary fiber, functional food, Physical properties, Sensory evaluation.

### INTRODUCTION

Many reports have highlighted that the intake of dietary fiber is much lower than the recommended value, resulting in a number of serious diseases such as cancer, obesity, diabetes, blood pressure, and cardiovascular problems (Wood, 1994; Welsh *et al.*, 1994; Truswell, 2002; Mellen *et al.*, 2008). Therefore, attempts have been made to increase the fiber intake of the diet by inclusion of fiber sources in different foods. The target foods are mainly those of high consumption, particularly bakery products. The main sources of fibers used commonly are cereal bran, fruits and vegetable peel, and polysaccharides derived from different seeds as they are available world-wide and economical (Mohamed and Hamid, 1998; Brennan and Samyue, 2004; Sudha *et al.*, 2007a,b). Different sources of dietary fiber

have been added to the cakes to increase the dietary fiber content. Sreenath *et al.* (1996) used seed hull of field beans, waste pulp of pineapple, and whole wheat in production of cakes which resulted in about 4-6% increase in dietary fiber. Masoodi *et al.* (2002) added apple pomace to the cakes recipe and found that the cake weight, shrinkage and uniformity index increased while cake volume and symmetry index decreased. Addition of more than 15% corn resistant starch in production of sponge cakes (Majzoobi *et al.*, 2014a) and muffins (Baixauli *et al.*, 2008) reduced the overall quality of the cakes. Gómez *et al.* (2010) reported that no more than 20% microcrystalline cellulose resulted in a layer cake with sensory characteristics very similar to those of the control. According to Kim *et al.* (2012) about 9% of *Opuntia humifusa* as a source of dietary fiber in sponge cake

<sup>1</sup> Department of Food Science and Technology, Shiraz University, Shiraz, Islamic Republic of Iran.

\* Corresponding author; e-mail: majzoobi@shirazu.ac.ir



improved physical quality and taste of the cakes. Ren and Shin (2013) found that addition of 10% cross-linked resistant rice starch resulted in a Korean cake with acceptable sensory quality. The influence of oat and wheat bran on batter and cakes and biscuits were studied by Gómez *et al.* (2010) and McMinn *et al.* (2007). Majzoobi *et al.* (2013) determined the effects of rice bran on the textural properties of sponge cakes. The effects of different particle sizes and levels of wheat bran of reduced phytic acid content on the nutritional, sensory, and physical properties of cake were studied by Majzoobi *et al.* (2014b). Based on the results obtained from previous studies, it was found that increasing the fiber content of the foods was challenging since it may negatively affect the sensory and physical properties of the foods. Particle size, percentage and type of the fiber are important factors affecting the quality of the final products.

A product derived from oat is oat fiber. It is generally produced after purification of the bran and is mainly composed of cellulose, hemicelluloses, and lignins and hence is a rich source of insoluble fiber (about 90%) with no fat or protein and can be used to enhance the fiber content of the foods without increasing fat or protein content of the product (Gularte *et al.*, 2012). It is available commercially and has been used recently in the production of gluten-free cakes (Gularte *et al.*, 2012). The results showed that oat fiber increased batter viscosity without modifying the cake specific volume.

Cakes are favorite foods but of low fiber content. Therefore, increasing the fiber content of the cakes can enhance the nutritional quality of these products. On the other hand, oat and its products have achieved a very positive consumer image because of the health benefits that have been associated with the consumption of fiber products. Therefore, addition of oat fiber to the cake and other products may receive good consumer attention. In our literature reviews, no information on the effects of oat fiber on the quality of sponge cakes was found. The main objective of this study was to examine

the potential of oat fiber in production of sponge cake and to determine the most appropriate level of oat fiber resulting in an acceptable product.

## MATERIALS AND METHODS

### Materials

Wheat flour, white fine sugar, low fat milk, sunflower oil, and fresh whole eggs were locally purchased. Baking powder (containing sodium bicarbonate and tartaric acid) and vanilla powder (with commercial name of Zamen, Iran) were obtained from local market. Wheat flour contained  $11.32 \pm 0.23\%$  moisture,  $9.53 \pm 0.30\%$  protein,  $0.38 \pm 0.20\%$  fat,  $0.50 \pm 0.10\%$  ash. Commercial oat fiber was provided by Karen Nutrilife Co., Tehran, Iran. It contained 91.5% fiber, 0.12% fat and 0.1% protein as determined using the Approved Methods of the AACC (2000) and was in the form of a fine creamy powder. Other chemicals used were of analytical grade and were purchased from Merck, Darmstadt, Germany.

Cakes were prepared according to the following recipe: 100 g cake flour, 75 g sugar, 56 g whole fresh eggs, 31.25 g oil, 62.5 g low fat milk, 3.2 g baking powder and 0.45 g 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.

### Batter Preparation

Sugar, eggs, and vanilla were whipped well in a household mixer (Kitchen–Moulinex mixer, Model HM 1010, Beijing, China) at medium speed (speed 4 on the mixer), for 2 minutes. Then, milk was added and mixed at the same speed until a thick cream was obtained (for 2 minutes). Flour was sieved three times along with baking powder with or without oat fiber and added gradually to the cream and mixed slightly

using a plastic spoon. Sunflower oil was added to the recipe and gently mixed to obtain cake batter.

### Determination of the Batter Density

A glass-tube of known weight was first filled with batter and the weight of batter was obtained. Then, the same glass-tube was filled with distilled water and the volume of the water was determined. The weight of the batter divided by the volume of the distilled water determined the batter density. The experiment was conducted in triplicates.

### Determination of the Batter Bostwick Number

The Bostwick number of the batter was determined using a Bostwick consistometer at ambient temperature ( $20\pm 0.5^\circ\text{C}$ ). The distance moved by the batter (100 g) for 30 seconds was determined as Bostwick number, which has negative correlation with batter consistency (Baeva *et al.*, 2000).

### 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  $180^\circ\text{C}$  until a gold crust was formed (35 minutes). After baking, the pans were left at room temperature for 1 hour to cool down and then the cakes were removed from the pans. Later, they were packed in polyethylene bags, coded and sealed to avoid moisture loss, and were stored at  $25^\circ\text{C}$  for further examination.

### 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).

### Color Evaluation

The color of cake crust and crumb were determined using the method described by Afshari-Jouibari and Farahnaky (2011). A sealed wooden box (50×50×60 cm) with interior white color was prepared. A white light lamp was fixed at inside top door of the box. The sample was placed inside the box with fixed distance from the lamp (50 cm). A digital camera (Canon, Model IXUS 230 HS, 14.0 Megapixels, Japan) was placed vertically at 25 cm distance from the sample. The angle between the lens and the sample was  $45^\circ$ . The resolution, contrast, and lightness of all images were set to 300 dots per inch (dpi), 62 and 62%, respectively. Pictures were taken from at least 5 different points of each sample and saved in JPEG format. Adobe Photoshop 11 was used to determine the lightness (L-value), redness-greenness (a), and blueness-yellowness (b) values of the samples.

### 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 using a TA-XT2 texture analyzer (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. The crumb was compressed to 25% of its initial height, at pretest speed of  $5\text{ mm s}^{-1}$ , test speed of  $0.25\text{ mm s}^{-1}$ , with a 10 second delay between the first and second compression. From the TPA profile, the peak force of the first compression cycle, cake hardness,



cohesiveness, springiness and gumminess were determined as described by Steffe (1996).

### 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, ages 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) (Stone and Sidel, 2004).

### Statistical Analysis

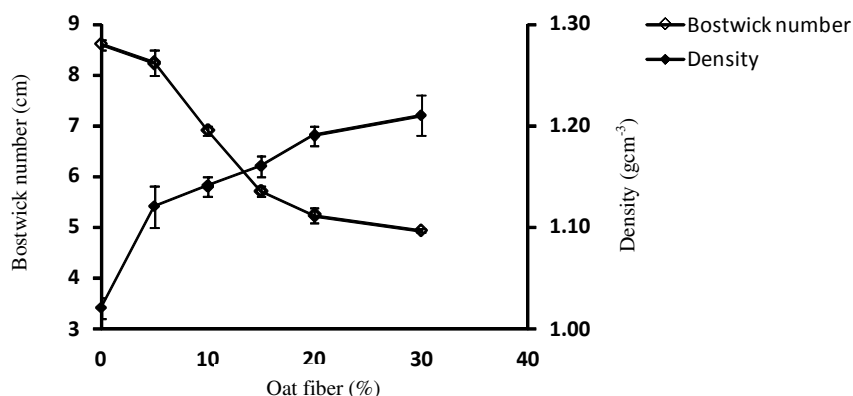
The tests were performed at least in triplicates. Values reported in figures and tables are the average of triplicates  $\pm$  standard deviation. A completely randomized design was utilized to determine significant differences among samples from analysis of variance (ANOVA). Duncan's multiple range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

## RESULTS AND DISCUSSION

### Effect of Oat Fiber on Batter Properties

Determination of batter consistency and density is important since they affect handling and correct dosing of the batter as well as cake physical properties such as volume and texture (Gómez *et al.*, 2007). Based on the results (Figure 1), with increasing the oat fiber content, the Bostwick number decreased from 8.60 to 4.93 cm. Bostwick number is negatively correlated with consistency, hence, the batter consistency increased with addition of oat fiber. The increase in the batter consistency was related to the high water absorption of the oat fiber. Oat fiber can increase the water binding capacity of the batter and reduce the amount of free water available to facilitate the movement of the particles in batter and, consequently, gives high batter consistency. Similar to this study, Rosell *et al.* (2009) and Gómez *et al.* (2010) reported that the addition of insoluble fibers increased cake batter density. Gularte *et al.* (2012) found that 10% oat fiber could increase up to 10 g water  $g^{-1}$  solid the water retention capacity of cake batter.

Batter density negatively correlates with the air quantity of the batter. Figure 1 shows that with increase in the oat fiber level, batter density increased from 1.02 to 1.21 g  $cm^{-3}$ , indicating that, probably, less air



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

bubbles were entrapped in the batter. Similarly, Gómez *et al.* (2010) reported an increase in batter density with increase in the level of different fibers. Ronda *et al.* (2011) have indicated that the quantity of air incorporated was lower in a batter of high consistency and density.

### Effects of Oat Fiber on Physical Properties of the Cakes

Figure 2 shows the cross-section of the cakes containing different levels of oat fiber. Different levels of oat fiber had significant effects on cake height, density, and volume (Table 1). The highest cake height was 6.20 cm and was obtained at 30% oat fiber, while the lowest height was 4.72 cm and belonged to the control. The density of the cakes decreased from 0.405 to 0.357 g cm<sup>-3</sup> as the level of the oat fiber increased from 0 to 30%. Opposite trend was observed for the cake volume. Therefore, the highest volume (586.84 cm<sup>3</sup>) 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<sup>3</sup>). Similarly, Sudha *et al.* (2007a) reported that addition of 0 to 30% apple pomace to the sponge cake reduced cake

volume and increased cake density possibly due to the high ability of the apple pomace to preserve water. Density and consistency of the batter are important characteristics affecting cake volume, height, and density.

The volume and density of the cakes are mainly dependent on the capacity of the batter to retain air during mixing, strength of the air bubble cell wall to expand properly during baking and stand after baking, and on starch gelatinization temperature (Lakshminarayan *et al.*, 2006; Lee *et al.*, 2005). The influence of oat fiber on cake volume and density can be explained by the increase observed in batter consistency and density (see Figure 1) that slows down the rate of gas diffusion, providing enough strength for the cake to keep the expanded air cells during baking and allowing its retention during the early stages of baking (Capriles *et al.*, 2008; Lebesi and Tzia 2011). It is possible that the oat fiber increased starch gelatinization temperature by reducing the amount of water for starch gelatinization. The increase in starch gelatinization temperature delays the change of the batter from a fluid, aerated emulsion to a solid, porous structure allowing the air bubbles to expand by the carbon dioxide gas and water vapor properly before the cake sets and, thus, the cake to increase its

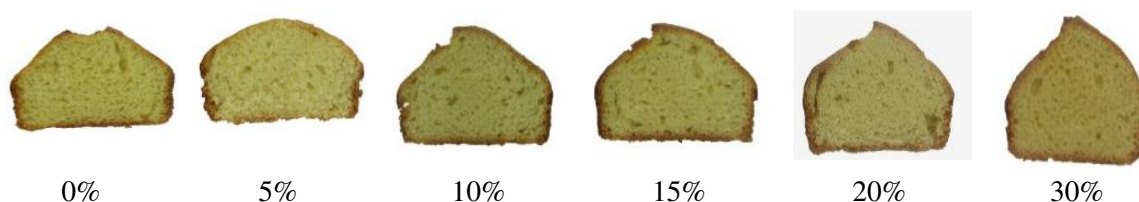


Figure 2. Cross-section of the cakes containing different levels of oat fiber.

Table 1. Effect of different contents of oat fiber on cake density, height and volume.<sup>a</sup>

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

<sup>a</sup> Values followed by different letters in the same column are significantly different (P < 0.05).

**Table 2.** Effect of different contents of oat fiber on textural properties of the cake.<sup>a</sup>

Oat fiber (%)	Hardness (Kg)	Cohesiveness	Springiness (mm)	Gumminess (Kg)
0	4.21±0.15 <sup>f</sup>	0.860±0.010 <sup>a</sup>	0.958±0.002 <sup>a</sup>	0.370±0.006 <sup>f</sup>
5	4.62±0.30 <sup>e</sup>	0.773±0.002 <sup>b</sup>	0.913±0.002 <sup>b</sup>	0.365±0.002 <sup>e</sup>
10	5.66±0.18 <sup>d</sup>	0.730±0.002 <sup>c</sup>	0.887±0.002 <sup>c</sup>	0.423±0.003 <sup>d</sup>
15	6.20±0.10 <sup>c</sup>	0.716±0.002 <sup>d</sup>	0.876±0.001 <sup>d</sup>	0.454±0.001 <sup>c</sup>
20	6.65±0.22 <sup>b</sup>	0.707±0.002 <sup>e</sup>	0.865±0.002 <sup>e</sup>	0.480±0.002 <sup>b</sup>
30	6.93±0.31 <sup>a</sup>	0.665±0.002 <sup>f</sup>	0.859±0.002 <sup>f</sup>	0.471±0.002 <sup>a</sup>

<sup>a</sup> Values followed by different letters in the same column are significantly different (P< 0.05).

volume for a longer time. In addition, fibers can positively affect cake volume since they can support the air bubbles cell walls inside the cake and prevent them from rapid collapse after removing the cakes from the oven and during storage (Majzoobi *et al.*, 2011).

The textural properties of the cakes are important characteristics as they are related with consumer acceptance. The effect of fiber on the textural properties of the cake is shown in Table 2. Hardness (firmness) measures the maximum force required for breaking the cake structure. Gumminess indicates the energy required for disintegration of the cake to a state ready for swallowing. The hardness and gumminess followed a similar trend and both of them increased with increasing oat fiber content. The results are in agreement with Grigelmo-Miguel *et al.* (1999). Although a negative correlation between cake volume and its hardness has been reported (Gómez *et al.*, 2010), this was not the case in this study. The moisture of the cakes and the interactions between oat fiber components with those present in the batter such as gluten, starch, sugar, and fat may also affect hardness of the cakes which needs further

investigation. Gularte *et al.* (2012) reported that the oat fiber had no effect on gluten-free cake volume while increased cake hardness. Cohesiveness measures the internal resistance of the cake structure and the degree to which the cake can be deformed before it breaks. Springiness, noted also as elasticity, indicates how easily a piece of cake returns to the original size after being pressed slightly by hand or with the mouth. Based on the results, the cohesiveness and springiness of the cakes decreased with increase in the percentage of the oat fiber.

#### Effect of Oat Fiber Concentration on Color Characteristics of Cakes

As can be observed in Table 3, crust color became darker (lower L-values), less reddish (lower a-values), and more yellowish (higher b-values) when fiber was added. Crust color is affected by Maillard and caramelization 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 can act as a buffer) and changes in water

**Table 3.** Effect of different contents of oat fiber on cake color.<sup>a</sup>

Oat fiber (%)	Crumb (L)	Crumb (a)	Crumb (b)	Crust (L)	Crust (a)	Crust (b)
0	79.3±1.5 <sup>d</sup>	-7.7±1.2 <sup>c</sup>	42.3±0.6 <sup>d</sup>	40.3±0.6 <sup>a</sup>	8.7±0.6 <sup>a</sup>	26.7±2.1 <sup>b</sup>
5	75.0±1.0 <sup>c</sup>	-8.0±0.0 <sup>c</sup>	43.0±1.0 <sup>d</sup>	38.3±0.6 <sup>b</sup>	7.0±1.0 <sup>b</sup>	27.0±1.0 <sup>ab</sup>
10	69.0±1.0 <sup>b</sup>	-10.0±1.0 <sup>b</sup>	44.6±0.5 <sup>c</sup>	36.0±1.0 <sup>c</sup>	5.3±1.5 <sup>c</sup>	28.3±1.5 <sup>ab</sup>
15	63.0±1.0 <sup>a</sup>	-12.0±1.0 <sup>ab</sup>	45.4±0.3 <sup>b</sup>	35.0±1.0 <sup>c</sup>	3.0±1.0 <sup>d</sup>	28.7±0.6 <sup>ab</sup>
20	62.0±1.0 <sup>a</sup>	-12.7±1.5 <sup>a</sup>	46.7±0.3 <sup>a</sup>	33.7±0.6 <sup>d</sup>	1.0±1.0 <sup>e</sup>	29.0±1.0 <sup>a</sup>
30	61.0±1.0 <sup>a</sup>	-13.0±1.0 <sup>a</sup>	47.3±0.2 <sup>a</sup>	30.0±1.0 <sup>e</sup>	-1.0±1.0 <sup>e</sup>	30.7±1.5 <sup>a</sup>

<sup>a</sup> Values followed by different letters in the same column are significantly different (P< 0.05).

content 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*- and *a*-value decreased. The *b*-value increased only when more than 15% oat fiber was added. The effects of the oat fiber on the moisture content and the porosity of the crumb may affect crumb color as reported by Grigelmo-Miguel *et al.* (1999).

### Sensory Evaluation

Sensory evaluation data of the cakes are presented in Table 4. The taste and texture of the cake improved when up to 20% oat fiber was added, while addition of 30% oat fiber resulted in inferior taste and texture of the cake. The panelists noted slightly bitter after-taste when 30% oat fiber was used. Although the scores given to the crust and crumb color decreased with increase in fiber level from 0 to 20%, all the scores were in the range of good to excellent. However, a remarkable decrease in the cake color was observed when 30% oat flour was added. Regarding the overall acceptability, it can be concluded that the inclusion of oat fiber up to 20% resulted in cakes with higher approval by the panelists. Nevertheless, the overall acceptability of the cakes containing 30% oat fiber was the lowest compared to the other samples. The acceptability decrease may be related to the hardness of the texture and darkness of the color.

### CONCLUSIONS

Formulation of oat fiber cake was achieved in this study. Apart from increasing the fiber content of the cakes, inclusion of the oat fiber in the sponge cake recipe could increase the volume of the cakes. However, some undesirable effects such as increase in the cake hardness and darkness also occurred. The undesirable changes were detectable by the panelists when 30% oat fiber was used, while addition of less amount of fiber could improve the sensory attributes of the cakes. Therefore, to include oat fiber in the recipe of sponge cake, no more than 20% oat fiber is suggested.

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**Table 4.** Effect of different contents of oat fiber on sensory properties of cake.<sup>a</sup>

Oat fiber (%)	Taste	Crust color	Crumb color	Texture	Overall acceptability
0	3.3±0.2 <sup>d</sup>	4.6±0.1 <sup>a</sup>	4.6±0.1 <sup>a</sup>	3.4±0.2 <sup>c</sup>	3.7±0.1 <sup>c</sup>
5	3.2±0.1 <sup>d</sup>	4.5±0.1 <sup>a</sup>	4.5±0.1 <sup>a</sup>	3.4±0.1 <sup>c</sup>	3.9±0.1 <sup>cd</sup>
10	3.8±0.1 <sup>c</sup>	4.2±0.1 <sup>b</sup>	4.2±0.1 <sup>b</sup>	4.0±0.1 <sup>b</sup>	4.1±0.1 <sup>c</sup>
15	4.2±0.1 <sup>b</sup>	4.1±0.1 <sup>b</sup>	4.0±0.1 <sup>b</sup>	4.3±0.2 <sup>b</sup>	4.5±0.1 <sup>b</sup>
20	4.6±0.1 <sup>a</sup>	4.2±0.2 <sup>b</sup>	4.1±0.1 <sup>b</sup>	4.7±0.1 <sup>a</sup>	4.8±0.1 <sup>a</sup>
30	2.8±0.1 <sup>e</sup>	2.6±0.1 <sup>c</sup>	2.6±0.1 <sup>c</sup>	2.8±0.1 <sup>d</sup>	2.9±0.1 <sup>c</sup>

<sup>a</sup> Values followed by different letters in the same column are significantly different (P < 0.05).



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