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# The effect of replacing sucrose with Stevia (*Stevia rebaudiana*) leaf powder and extract on some pysico-chemical properties of cakes

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***Abstract***

In this study the effect of replacing sucrose with *Stevia* leaf powder and stevia extract on some properties of cakes was researched. Mineral composition, color parameters of cakes and viscosity of batters were measured. Elements found in samples were P, Ca, Mg, Na. Addition of stevia leaf powder or stevia extract increased amount of calcium (from 478.45 mg/kgto 1159.32 mg/kg in D group and 852.03 mg/kg in G group), magnesium (from 196.88 mg/kg to 508.72 mg/kg in D group and 852.03 mg/kg in G group) and sodium (from 5797.57 mg/kgto 11386.51mg/kg and9413.05 mg/kg in D and G groups, respectively) minerals in cakes. Substitution sugar with stevia leaf powder and stevia extract decreased the value of redness (*a**) of samples that were 11.98, 3.41 and 4.60 for A, D and G groups, respectively. According to sensory evaluation, cakes containing stevia products had less score than other sugar adding samples by panelists.

***Keywords***: Cake, stevia, color, viscosity, apple and carrot pures, minerals, sensory properties, ICP-AES

## 1. Introduction

Cakes are tasty baked products that are consumed by people from all over the word. Cakes have various definitions and formulations [1]. A cake is basically a semi-dry foam due to the setting of a liquid medium extended by gas delivered from dissolved chemicals [2]. Cakes usually contain relatively high levels of sucrose,wheat flour, water, eggs, milk, shortening, flavors, and chemical leavening systems [3]. Sucrose is a dominant ingredient in cakes. In the cakes, sucrose delays starch gelatinization and protein denaturation [1]. Additionally, sucrose helps incorporating air cells into the batter during creaming and contributes good structure, flavor, and texture to the product [4]. Besides its proven significant functions, excessive consumption of sugar leads to differenthealth problems like diabetes and obesity.

Therefore, researchers nowadays attempt to produce healthierfoods by reducing the amount of sucrose or substituting sucrose with artificial sweeteners. Stevia extracts have high intensity sweetness that generally used as sucrose replacer in cake formulations [5]. *Stevia rebaudiana* Bertoni is a plant native to the northern part of Paraguay in South America. It consists of various sweetening compounds because of their glucose sidechain such as stevioside and rebaudioside A [6,7]. These glycosides can be easily removed with water [8]. Stevia leaves have the stevioside [9] which is the dominant sweetness substance, 300 times sweeter tasting than sucrose [4,10]. Other important sweetness substance is Rebaudioside A which is 250-450 times as sweet as sucrose [11]. Scientific studies does not prove that stevia extracts have a potential toxicity to humans [12].

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Many researchers have examined the functionality of different artificial sweeteners in several bakery products includingstevia leaves in yogurt cake [13], stevia (Rebaudioside A powder) in *Kuih Baulu* [14], sucralose in muffins [15], erythritol-sucralose in chiffon cakes [16], stevioside in cake [4], dextrin and sucralose in chiffon cake [17], and aspartame and/or Acesulfame-K in sponge cake [18]. In this study, stevia leaf powder and stevia extract substituted for sucrose were used in cakes and at the same time apple puree and carrot puree were used to mask bitterness of stevia. It was aimed to determine some physicochemical properties and mineral content of cakes having different formulations.

## 2. Materials and Methods

Cake ingredients (wheat flour, milk, margarine, egg, sucrose, baking powder, salt), stevia leaf powder, apple and carrot were purchased from the local market in Konya (Turkey).Apples and carrots were pulped before adding to formulation.

### 2.1.1.Preparation of stevia extract

Stevia extract was prepared according to modified method used by Woelwer et al. [19]. 12 g of stevia leaf powder was mixed with 100 mL of distilled water and kept in a water bath at 100°C for 30 min. After that, suspension was centrifuged for 15 min at 6000 rpmand the aqueous phase was filtered through the 0.45 µm membrane filter.

### 2.1.2.Preparation of the cakes

The cake batters were preparation according to method proposed by Wilderjans et al. [1] with some modifications. Batter ingredients were mixed by Kitchen Aid mixer in three stages [20]. The sucrose was mixed with melted margarine until become like a cream for 2 min at low speed.The whole egg was added to mixture and mixed for 2 min at low speed. Finally milk, wheat flour, baking powder and salt added and mixed for 3 min at low speed. The each teflon pan was filled with 75 g of batter and baked at 190°C for 30 min. After baking, cakes were cooled at room temperature for 2 h [21].

This study had nine different groups: A, B, C, D, E, F, G, H and I. A, B and C groups prepared with sucrose. D, E and F groups were prepared using the replacement of sucrose with stevia leaf powder of equal sweetness. In these groups 6 g stevia leaf powder was added instead of 120 g sucrose because sweetness of 1 g of stevia is equivalent to 20 g of sucrose [22].

Stevia extract was used in G, H and I groups as sucrose substitute (50 ml extract obtained from 6 g of stevia leaf powder). While apple puree was added to B, E and H groups, C, F and I groups contained carrot puree. The cake formulations are shown in Table 1.

### 2.2.Method

### 2.2.1.Determination of moisture content

Moisture content (hot air oven) was determined using standard method of the AOAC [23].

### 2.2.2.Determination of mineral content

15 ml of pure $NHO_3$ and 2 ml $H_2O_2$ (% 30 w/v) were added on 0.5 g of sample into incineration cup. After burning of sample in a MARS 5 microwave oven at 210 ˚C, samples were filtrated through whatman No 42. The filtrates and standard solutions at known concentrations were analysed by Inductively coupled plasma atomic emission spectroscopy (ICP-AES) concurrently [24].

- Instrument : ICP-AES (Varian-Vista)
- RF Power : 0.7-1.5 kw (1.2-1.3 kw for Axial)
- Plasma gas flow rate (Ar) : 10.5-15 L/min. (radial) 15“ (axial)
- Auxilary gas flow rate (Ar) : 1.5“
- Viewing height : 5-12 mm
- Copy and reading time : 1-5 s (max. 60 s)
- Copy time : 3 s (max. 100 s)

### 2.2.3.Viscosity of batters

The apparent viscosity (AV) of cake batters was quantified at five different rotational speeds (2.5, 5, 10, 20, 50 rpm)using a Brookfield model rotational viscometer (Lab Line, Model no. 4535, Lab Line Instruments, Inc., Melrose Park, ILL., UK, Appropriate spindle no. 7). Sample was placed into a test tube at amount covering the immersion grooves on the spindle shafts. The flow curves, AV versus rotational speed of all samples were arranged by using the power law model [Eq. (1)] and calculated with linear regression analysis [25]. The flow behavior index (n), consistency index (*k*) values and determination coefficients ($R^2$) were designated by modeling the rotational speed versus AV values to power-law model.

$$\eta_\alpha = k\,\gamma^{(n-1)} \qquad (1)$$

η is the AV (mPa s), *k* (Pa $s^n$) is the consistency index, γ is the rotational speed ($s^{-1}$) and n (dimensionless) is the flow behavior index.

### 2.2.4.Color analysis

Color measurements were performed using a chromameter (model CR-400, Konica Minolta, Osaka, Japan) with illuminant D65 (L*, a* and b* values), 2° observer angle, 8 mm illumination range in mode Diffuse/O. Color coordinates L* (luminance), a* (redness, +60, red; -60, green) and b* (yellowness, +60, yellow; -60, blue) were determined in accordance with CIE L*a*b* color coordinate system (CIE, 1976).Two different readings were taken on exterior surfaces of cake samples in each group for measurements.

### 2.2.5.Sensory evaluation

The sensorial properties of samples (taste, flavor, color, texture, appearance, homogeneity of pores and overall acceptance) were evaluated by 8 semi-trained panelists. Each sample was assigned randomly using two-digit numbers. Panelists gave points for samples on 5-point hedonic scale according to liking and disliking(5: like it very much, 4: like it, 3: neither like nor dislike it, 2: dislike it, 1: dislike it a lot).

### 2.3.Statistical analyses

All results were stated asmean±standard deviation (MSTAT C) of fruit samples [26].

## 3. Results and Discussions

The moisture content of cake samples is shown in Table 2. The addition of apple or carrot puree increased moisture content. The moisture content of cakes containing carrot puree is determined to be higher than that of others.While the highest moisture content was belonged to I group (57.60%), the lowest value was determined for A group (42.65%).Cakes prepared with sugar had lower moisture content than other groups including stevia leaf powder or stevia extract due to high water holding capacity of stevia leaf powder [27].The higher water absorption capacity of stevia is due to its protein content. It is known that proteins enhance water holding capacity because of their swelling ability [22]. The other reason why G, H and I groups had high moisture content could be due to the usage of stevia as a sweetener in the form of liquid. Color parameters belonged to cakes were given in Table 2. Stevia leaf powder and stevia extract had significant effects on *a** values of D, E, F and G, H, I groups, respectively. *L**, *a** and *b** values of D, E and F groups were lower than other groups. The highest *L** values were observed in G, H and I groups.

The minimum *a** values were observed in D, E and F groups that contained stevia leaf powder. A, B and C groups had highest *a** values. These differences could be caused by chlorophyll pigments of stevia leaf [28].The stevia extract is dark brown in color asthe color pigments of stevia is diffused in the water during hot extraction process [29].

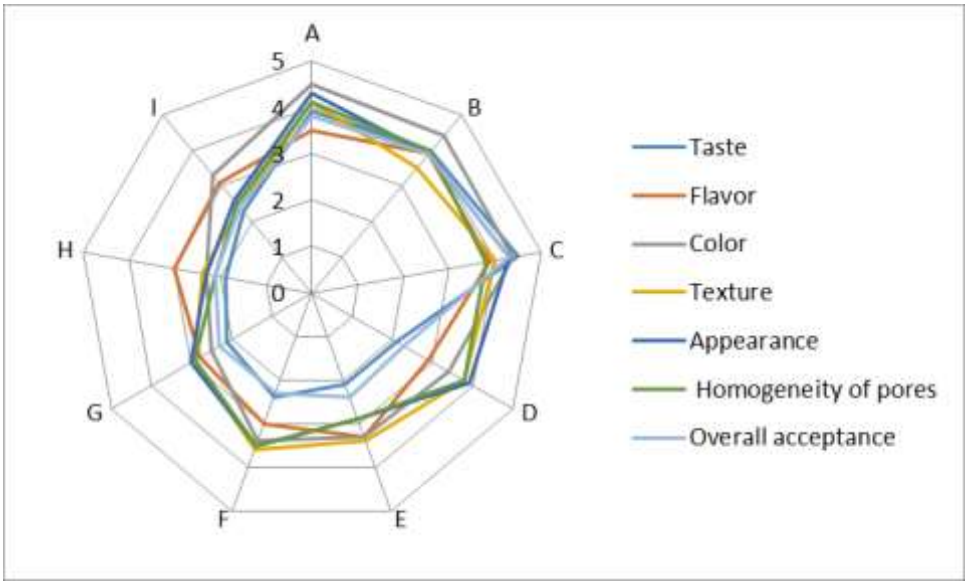


***Figure 1***. Sensory evaluation of cakes including different materials as a sweetener

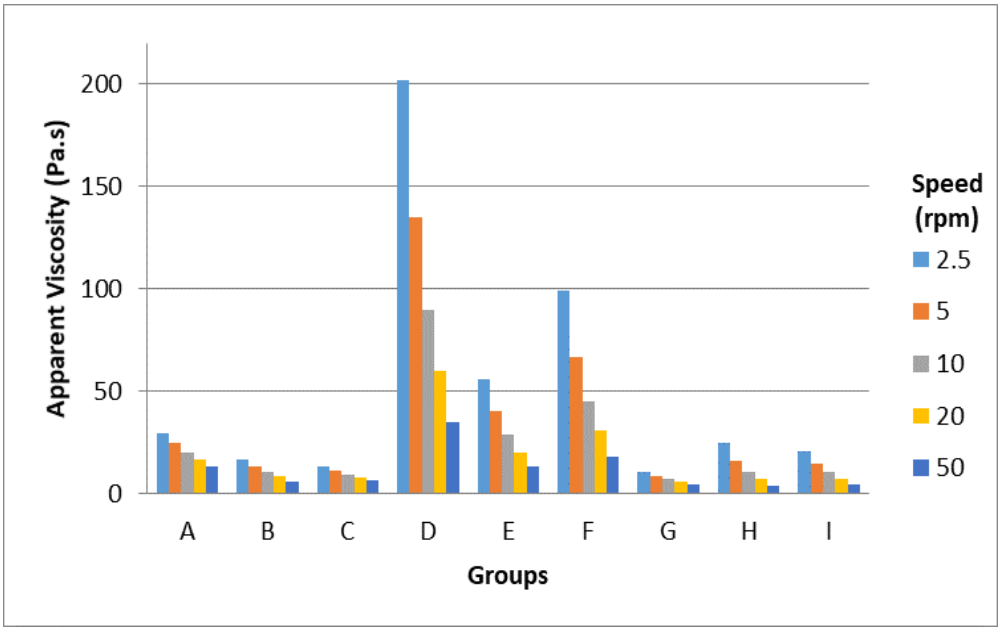


***Figure 2***. Apparent viscosity of each group as a function of rotational speed

***Table 1.*** Formulations used in manufacturing of cakes

| | Groups | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Formulation** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** |
| Wheat flour (g) | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| Margarine (g) | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 | 70 |
| Egg (g) | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Milk (g) | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 | 80 |
| Baking powder (g) | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Salt (g) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Sucrose (g) | 120 | 120 | 120 | - | - | - | - | - | - |
| Stevia leaf powder (g) | - | - | - | 6 | 6 | 6 | - | - | - |
| Stevia extract (mL) | - | - | - | - | - | - | 50 | 50 | 50 |
| Apple puree (g) | - | 20 | - | - | 20 | - | - | 20 | - |
| Carrot puree (g) | - | - | 20 | - | - | 20 | - | - | 20 |

***Table 2.*** The moisture content and color properties of cakes

| Cakes | Moisture % | *L** | *a** | *b** |
|---|---|---|---|---|
| A | 42.65±1.02* | 45.59±3.94 | 11.98±2.99 | 26.84±3.53 |
| B | 45.68±1.86 | 42.14±2.83 | 14.02±0.37 | 22.87±3.56 |
| C | 47.82±0.78 | 44.38±5.73 | 13.73±1.08 | 25.53±5.79 |
| D | 47.10±1.33 | 38.54±0.17 | 3.41±0.13 | 11.58±0.18 |
| E | 51.71±1.53 | 39.16±1.97 | 3.21±0.78 | 10.43±2.44 |
| F | 52.58±0.35 | 39.26±0.22 | 1.89±0.53 | 10.82±1.04 |
| G | 52.56±0.00 | 49.87±0.82 | 4.60±0.03 | 21.72±0.41 |
| H | 57.11±1.53 | 47.95±0.58 | 4.51±0.54 | 20.54±0.24 |
| I | 57.60±0.41 | 47.48±0.28 | 4.50±0.21 | 22.19±0.32 |

*mean±standard deviation

The mineral content of cakes is shown in Table 3. Analyzed mineral composition indicated that addition of stevia leaf powder or stevia extract increased amount of calcium, magnesium, sodium, phosphorus, sulphur and zinc minerals. While E group had the highest Ca (1213.35 mg/kg) and Mg (519.59 mg/kg) content, the maximum value for Na (11386.51 mg/kg) was found in D group. The highest iron content was found in D (35.25 mg/kg), E (33.76 mg/kg) and F (35.75 mg/kg) groups.Stevia is rich in important elements that are essential for organism and metabolic processes. The minerals determined in stevia leaves are potassium, calcium, magnesium, sodium, zinc and iron [30]. It was found in a research about mineral composition of stevia thatthe amounts of calcium, phosphorus, iron, sodium and potassium were 464.6, 11.4, 55.3, 190 and 1800 mg/100 g, respectively ([22]. It is an expected situation that the amounts of mentioned elementswere higher in cakes including stevia leaf powder or stevia extract than other cakes made with sugarwhen compared with studies about stevia.

Consistency index, flow behavior index, determination coefficient and viscosity values at different rotation speeds of batters are indicated in Table 4, and Figure 2 illustrated apparent viscosity dataof each group as a function of rotational speed. Apparent viscosity values were fitted to power-law model with high determination coefficients ($R^2$=0.956-0.999) and calculated by power-law equation.Batters showed a non-Newtonian flow due to decreasing of apparent viscosity with speed.It was observed that stevia leaf powder addition significantly increased the viscosity of batters while stevia extract decreased. Ozdemir et al. [31] reported that stevia added ice-cream mixes had lower viscosity than sucrose added samples.

Results of the sensory evaluation of cakes including different materials (sucrose, stevia leaf powder and stevia extract) as a sweetener are shown in Figure 1. It was observed that the cakes containing stevia products were liked less than other sugar adding samplesby panelists.

According to general acceptibility test, while the highest score was belonged to C, H had lowest point.The similar results were obtained in terms of taste. Stevia contains chlorophyll pigments, secondary metabolites and plant residues, besides glycosides that can contribute to reducing the sweetness and decreasing the acceptance [29]. Guggisberg et al. [32] indicated that the bitterness of yoghurt samples containing stevia was higher than that of others added sugar.

***Table 3.*** Mineral content (mg/kg) of cakes

| Minerals | A | B | C | D | E | F | G | H | I |
|---|---|---|---|---|---|---|---|---|---|
| Al | 0.87±0.02 | 3.34±0.02 | 0.25±0.03 | 25.33±0.19 | 22.83±0.25 | 24.11±0.12 | 1.66±0.02 | 2.28±0.06 | 1.94±0.03 |
| Mo | 0.24±0.04 | 0.10±0.02 | 0.25±0.01 | 0.30±0.02 | 0.23±0.02 | 0.04±0.01 | 0.12±0.01 | 0.22±0.01 | 0.05±0.01 |
| Ca | 478.45±3.50 | 581.87±6.00 | 477.59±7.66 | 1159.32±6.65 | 1213.35±5.04 | 1128.93±2.69 | 852.03±5.23 | 980.41±5.50 | 983.43±4.50 |
| B | 0.95±0.02 | 0.81±0.04 | 0.43±0.03 | 2.22±0.06 | 1.19±0.04 | 2.16±0.03 | 0.56±0.04 | 0.60±0.03 | 0.39±0.05 |
| Cd | 0.04±0.01 | 0.04±0.01 | 0.04±0.01 | 0.09±0.01 | 0.09±0.01 | 0.02±0.01 | 0.01±0.01 | 0.03±0.01 | 0.03±0.01 |
| Cr | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 | 0.09±0.01 | 0.00±0.00 | 0.00±0.00 | 0.00±0.00 |
| Cu | 1.18±0.06 | 0.37±0.04 | 0.19±0.04 | 0.99±0.03 | 0.84±0.05 | 1.13±0.05 | 0.66±0.06 | 0.63±0.06 | 1.45±0.07 |
| Fe | 5.83±0.07 | 7.44±0.06 | 5.92±0.07 | 35.25±0.07 | 33.76±0.07 | 35.75±0.09 | 9.18±0.06 | 9.24±0.03 | 11.85±0.06 |
| Mg | 196.88±4.63 | 242.51±6.06 | 200.37±6.50 | 508.72±6.51 | 519.59±6.50 | 493.67±5.51 | 413.13±4.01 | 466.39±4.50 | 462.22±3.53 |
| Mn | 1.58±0.06 | 2.29±0.07 | 1.67±0.08 | 7.71±0.07 | 7.59±0.06 | 7.48±0.07 | 4.79±0.06 | 5.08±0.06 | 4.79±0.06 |
| Na | 5797.57±6.50 | 6849.27±5.51 | 5843.23±5.52 | 11386.51±7.06 | 10244.52±8.67 | 9535.13±6.00 | 9413.05±4.60 | 10594.53±7.78 | 11027.33±6.03 |
| Ni | 1.88±0.07 | 0.59±0.06 | 0.28±0.05 | 0.58±0.06 | 0.45±0.06 | 0.29±0.05 | 0.31±0.03 | 0.00±0.00 | 2.91±0.07 |
| P | 2591.88±6.59 | 3024.96±7.00 | 2583.18±5.53 | 4753.08±6.00 | 4478.48±6.06 | 4335.26±6.02 | 4297.68±5.51 | 4551.46±5.50 | 4741.59±3.50 |
| Pb | 0.00±0.00 | 0.27±0.05 | 0.00±0.00 | 0.07±0.02 | 0.00±0.00 | 0.01±0.01 | 0.04±0.01 | 0.34±0.03 | 0.16±0.03 |
| S | 719.45±4.50 | 878.67±5.51 | 723.66±5.51 | 1303.29±5.51 | 1370.88±12.35 | 1191.28±5.51 | 1173.65±5.51 | 1262.27±4.52 | 1304.54±4.50 |
| Zn | 5.68±0.08 | 4.97±0.07 | 3.89±0.07 | 7.29±0.06 | 6.85±0.07 | 7.48±0.07 | 6.62±0.06 | 6.98±0.06 | 9.79±0.06 |

*mean±standard deviation

***Table 4.*** Consistency index, flow behavior index, determination coefficient and viscosity values at different rotation speeds of batters[a]

| Cakes | n Index | *k* Indeks (mPa.s$^n$) | $R^2$ | Viscosity (Pa.s) | | | | |
|---|---|---|---|---|---|---|---|---|
| A | 0.723 | 38413 | 0.999 | 29.40 | 24.70 | 20.00 | 16.5 | 12.70 |
| B | 0.663 | 22494 | 0.991 | 17.30 | 13.20 | 9.20 | 7.70 | 6.30 |
| C | 0.764 | 16242 | 0.981 | 14.40 | 10.90 | 8.50 | 6.80 | 7.30 |
| D | 0.416 | 324735 | 0.999 | 191.00 | 121.90 | 82.50 | 54.5 | 31.70 |
| E | 0.512 | 87692 | 0.965 | 58.10 | 40.00 | 27.60 | 16.5 | 14.10 |
| F | 0.437 | 165834 | 0.995 | 100.70 | 65.20 | 43.20 | 28.8 | 18.10 |
| G | 0.704 | 13572 | 0.991 | 9.50 | 8.60 | 7.20 | 6.00 | 3.80 |
| H | 0.381 | 44102 | 0.956 | 26.20 | 15.50 | 10.40 | 5.80 | 4.10 |
| I | 0.514 | 32086 | 0.995 | 21.10 | 14.30 | 9.90 | 7.00 | 4.80 |

[a]*k* and *n* (dimensionless) values were obtained by fitting rotational speed–viscosity data to power-law model, $\eta=k\Upsilon^{(n-1)}$, where η is the apparent viscosity, *k* is consistency index and n is flow behavior index.

## 4. Conclusions

The usage of stevia products in cakes positively affected moisture content and increased amount of Ca, Mg, Na, P, S and Zn minerals. *a**value decreased as the use of stevia products increased due to chlorophyll pigments included in stevia leaf. Apparent viscosity of batters was decreased with increase of rotational speed. The highest viscosity value was measured in groups containing stevia leaf powder compared with other groups. According to results of sensory evaluation, cakes including stevia products were less favored groups due to slightly bitter taste of stevia. However, the most favored group among stevia products added samples was D group prepared with only stevia leaf powder.

**Compliance with Ethics Requirements.** Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human / or animal subjects (if exist) respect the specific regulation and standards.

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