New Valley Journal of Agricultural Science
Published by Faculty of Agriculture, New Valley University, Egypt
DOI: 10.21608/nvjas.2023.184532.1153
Research Article Open Access

Impact of Using Oat Flour and Erythritol on Characteristics and Glycemic Index of Chiffon Cakes and Study the Effect of Erythritol on Cavity-Causing Bacteria

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Received: 31/12/2022
Revised: 16/01/2023
Accepted: 16/01/2023
Published: 16/01/2023

Abstract

Oats have a high content of β-glucan soluble fiber. Its consumption lowers cholesterol and the glycemic response. One of the main components of many baked confectionery goods is sucrose. Reducing the amount of refined sugar in food has become urgently necessary as a result of the growing understanding of the link between excessive sugar consumption and the emergence of chronic diseases. Oat flour in the chiffon cake formulation was replaced at three levels, 50, 75 and 100% with wheat flour and we had replaced sucrose with erythritol. Raw materials and prepared chiffon cake were analyzed for their chemical composition. The final product was evaluated for baking quality (weight, volume, specific volume), glycemic index (GI) and organoleptic Properties of chiffon cake. The inhibitory effects of erythritol on Streptococcus strains were examined. The results suggest that it could be seen that a significant increase in fiber and fat contents (10.1 and 6.52 respectively) and a decrease in carbohydrate content 68.79, in oat flour compared to wheat flour. Our results indicated that in the presence of erythritol was decreased the growth of S. sanguinis by 73%. Chiffon cake produced with oat flours and erythritol it was characterized with their higher content of moisture, ash and fiber. The highest weight (360.0 g) was given by adding 100% oat flour to the chiffon cake sample compared to 342.6 g for control cake. The GI were decreased as the levels of oat flour were increased and substituted sucrose with erythritol. Chiffon cakes prepared with 50% oat flour and 100% erythritol was decreased in sweetness when compared with chiffon cake control but was still acceptable.

Key words: chiffon cakes, erythitol, glycemic, ecavity- causing, organoleptic.

Introduction

Oat (*Avena sativa* L.) is characterized as starchy grain and easily cultivatable in all over the world. In comparison to other cereals, these cereals stand out from others because they include a lot of total protein, carbs (primary starch content), crude fat, dietary fiber (non-starch), unique antioxidants, and a lot of vitamins and minerals. Oats have a great nutritional value for both humans and animals due to their delicious flavor and ability to stimulate metabolic changes in the body (Peterson, 2004).

Dietary oats have long been known to relieve diabetes symptoms, lower cholesterol levels, prevent coronary heart disease, and reduce obesity. Numerous studies have shown that oats contain significant levels of β-glucan, which is advantageous to human health and is thought to be the cause of these health advantages. Oat contains 2.0 - 7.5% β-glucan, 13 - 20% protein, 2 - 12% crude fat, and roughly 60% starch (Aro et al., 2007).

Due to these nutritious benefits, there is more interest in oats being added to bakery goods. Cakes are an ideal technological vehicle for introducing non-wheat flours because, gluten is not required to produce a high-quality final product, as already shown by De lahera et al., (2012). Gutkoski et al., (2009) used oat flour when making cakes. They concluded that oats can be added to cakes to increase fiber content and lower the calorie amount.

The world's consumption of bakery goods is rising. The cake is undoubtedly one of the most delectable and beloved bakery items that is enjoyed by consumers of all ages (Etienne et al., 2017). Since customers are increasingly looking for quick meals that meet their sensory expectations, the main reasons for the increased consumption can be attributed to their superior sensory quality, usefulness, and convenience (Manisha et al., 2012). Recently, public health initiatives in several nations have been looking for solutions to the major issue of calorie-dense foods, particularly those high in sugar, in order to combat diabetes and its effects (Carrillo et al., 2012).

Sucrose is a key component of many foods, including cakes, biscuits, and jam. In addition to supplying vigor and sweetness, it serves as a tenderizer by retarding and limiting the development of gluten, raising egg protein denaturation temperatures, gelatinization of starch, and contributing to the volume and bulk (Psimouli and Oreopoulou, 2012 & Godefroidt et al., 2019). In turn, numerous studies have demonstrated the detrimental consequences of excessive free sugar consumption on health, particularly the odds of catching non-communicable diseases (Welsh et al., 2011), unfavorable changes in blood pressure, cancer risk factors, and serum lipids (Te Morenga et al., 2014 & Makarem et al., 2018). Researchers and epidemiologists have recently focused their attention on excessive sugar consumption since they believe it is a major factor in the growth in obesity prevalence (Malik et al., 2006 & Faruque et al., 2019).

Erythritol, a 4-carbon sugar alcohol with about 60-80% of the sweetness of sucrose, can be used in low-calorie foods due to the fact that it offers less calories than 0.5 Kcal/g, has no effect on blood sugar or insulin levels, and is non-cariogenic and non-toxic (Goossens and Röper, 1994 & Munro et al., 1998). Hydrogenated carbohydrates called polyols are utilized as sugar substitutes. Because of its numerous potential health advantages, interest has grown recently. They are low-digestible, low-energy, low-insulinaemic, non-cariogenic (sugar-free, tooth-friendly), low-glycemic (maybe useful in diabetes and cardiovascular disease), and low-glycaemic (perhaps helpful in obesity) (potentially helpful in the colon) (Livesey, 2003).

The aim of the current study was to examine physicochemical characteristics, GI, and organoleptic Properties of chiffon cakes prepared with oats flour as a 50, 75 and 100% substitute for wheat flour and evaluate the effect of complete sucrose replacement with erythitol to elaborate chiffon cakes. Also, study the effect of erythritol on ecavity- causing bacteria. The development of a chiffon cake with a relatively low glycemic index would help manage the obesity pandemic and preventing the onset of lifestyle-related diseases.

Materials and Methods

Materials

We bought our ingredients from Tanta's local markets: wheat flour, oat flour, sucrose, erythritol, sunflower oil, eggs, baking powder, vanilla, and salt.

Methods

Preparation of chiffon cakes

Chiffon cakes were made in compliance with Akesowan (2007), with a few changes **(Table 1& Figure 1)**.

Table 1. Formulation of chiffon cakes

Ingredients (gm)	C	M1	M2	M3
Wheat flour	100	50	25	-
Oat flour	-	50	75	100
Sucrose	72	-	-	-
Erythritol	-	72	72	72
Sunflower oil	30	30	30	30
Egg white	80	80	80	80
Egg yolk	55	55	55	55
Baking powder	3	3	3	3
Vanilla	1	1	1	1
Salt	0.5	0.5	0.5	0.5
Water	25	25	25	25

C = control sample M1= chiffon cakes prepared with 50% oat flour and 100% erythritol, M2= chiffon cakes prepared with 75% oat flour and 100% erythritol, M3= chiffon cakes prepared with 100% oat flour and 100% erythritol

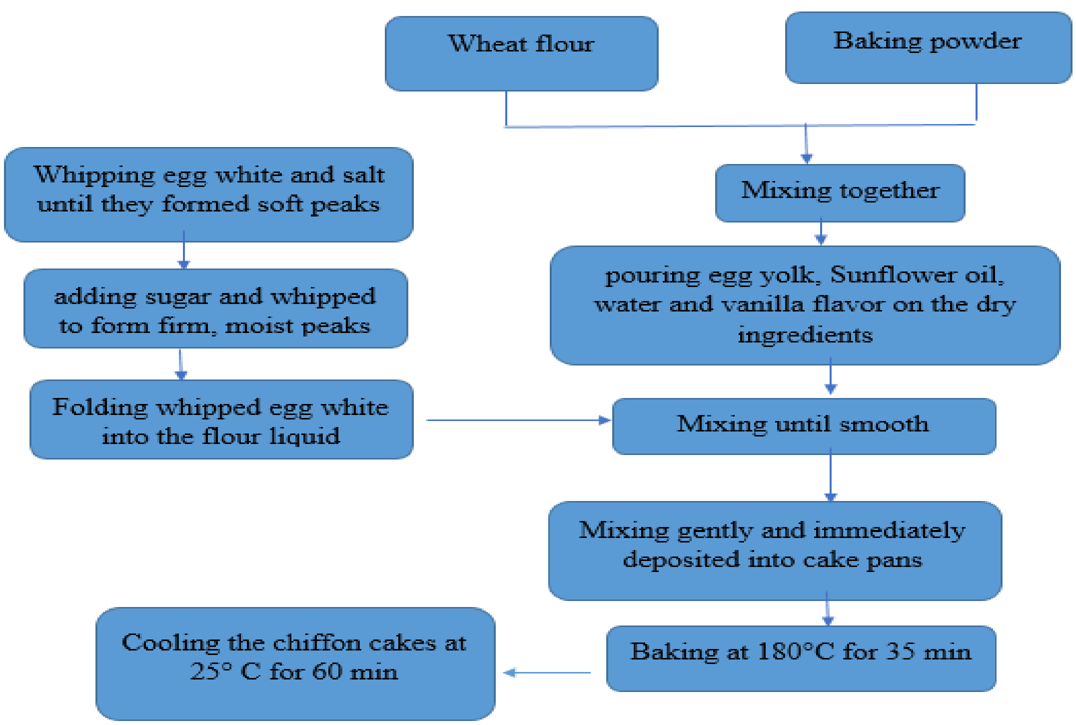


Figure 1. Scheme diagram for preparation of chiffon cakes samples

C = control sample M1= chiffon cakes prepared with 50% oat flour and 100% erythritol, M2= chiffon cakes prepared with 75% oat flour and 100% erythritol, M3= chiffon cakes prepared with 100% oat flour and 100% erythritol

Analytical methods:

Chemical analysis

Moisture, ash, crude protein, fat and crude fiber contents were assessed in raw materials and samples using the techniques described in A.O.A.C. (2010). Carbohydrates were calculated by difference as mentioned as follows: Carbohydrates = 100 – (% protein + % fat + % ash + % crude fiber)

Baking quality of chiffon cakes

After the chiffon cake had cooled for 60 minutes, its weight was determined. Using the rape seed displacement method as described by A.A.C.C. (2000) the volume of a chiffon cake was measured. Calculating the specific volume of chiffon cake required dividing the volume (cm3) by their weight (g).

Glycemic index measurement

The individuals' capillary blood was drawn for the glycemic index test in order to gauge their fasting blood sugar levels. Additionally, subjects were instructed to consume pure glucose as a check. The blood was drawn every 30 minutes (0, 30, 60, 90, and 120). After analyzing the food for two hours, a glucometer was utilized to perform the glycemic index test (Auto-coding OSANG, Korea). Glycemic index is derived by find the incremental area under curve by the trapezoidal (FAO, 1998).

Testing bioactivity of erythritol against cavity- causing bacteria

To create log phase cells, different types of streptococci were first grown in 5 ml of BHI broth (Merck, Germany). The cultures were transferred (2%) to fresh BHI that had been treated with 1% sucrose after being incubated at 37 °C for roughly 16 hours. Growth media included (330 mM) erythritol (Soderling and Hietala-Lenkkeri, 2010). Erythritol stock solutions were made in distilled water, sanitised through a 0.2 Millipore filter (Axiva, India), and then aseptically added to the medium at the proper concentration. The control medium has no erythritol in it. The test cultures were cultured for 24 hours at 37°C in a 5% CO_2 incubator with slow shaking. By measuring the absorbance at a wavelength of 600 nm, growth was tracked. The growth curves in late log phase were used to calculate the inhibitory effects of erythritol.

Organoleptic properties of chiffon cake

Chiffon cakes were evaluated according to the method described to McCullough et al. (1986) with some modification: Ten panelists of staff members and students of food science and technology Dept. at Faculty of Home Economics, Al-Azhar University were given four random samples (1 cm x 1 cm x 1 cm) from chiffon cakes. Mini sponge cakes were evaluated for crumb color (10), tenderness (10), moistness (10) and sweetness (20).

Statistical analysis

Data were analyzed by ANOVA (Analysis of variance) using Duncan's multiple range test and $p<0.05$ was used to indicate significance between different treatments. All the analyses were done with SPSS (Statistic Program Sigma stat, Statistical Soft-Ware, SAS Institute, Cary, NC).

Results and Discussion

Chemical composition of the flours used in chiffon cakes

Chemical composition of wheat flour and oat flour was determined, and the obtained results are found in **Table 2**. The moisture content in oat flour was 11.5%. It was the lowest moisture content compared to wheat flour. It could be observed that, no significant differences at $P \leq 0.05$ were noted between oat flour and the wheat flour for protein. The ratio of ash (1.59%) of oat flour was significantly ($p \leq 0{:}05$) higher than that of wheat flour (0.73%). The fiber value of the oat flour was 10.1% compared to 1.81% for the wheat flour. On the other hand, oat flour was lower in carbohydrate (68.79%), when compared to wheat flour. The results obtained may be agreement with the findings of Mehder (2013). As a result, oat flour is a good source of dietary fiber and ash, which may be used to make high-fiber chiffon cakes.

Table 2. Chemical composition of the flours used in chiffon cakes.

Components	Wheat flour	Oat flour
Moisture	12.27[a]	11.5[b]
Crude Protein	12.54[a]	13.00[a]
Lipid	1.70[b]	6.52[a]
Ash	0.73[b]	1.59[a]
Crude Fiber	1.81[b]	10.1[a]
Carbohydrates	83.22[a]	68.79[b]

Mean followed by different letters in the same column are significantly different by Duncan's multiple test ($P \leq 0.05$).

Chemical composition of chiffon cakes

Data presented in **(Table 3)** showed the chemical composition of chiffon cake prepared by replacement wheat flour with oat flour and sucrose with erythritol. Chiffon cake produced with oat flours and erythritol it was characterized with their higher content of moisture, fat, ash and fiber and there were no significant differences in protein content compared with control. Generally speaking, oat flour

appears to be a natural source of elements, abundant in dietary fibre, with low glycaemic index, antioxidant activity, and thermal stability during food processing. Oat flours might thus be promoted in the food business as a useful, secure ingredient. These findings concur with those of Zaki et al., (2018).

Table 3. Chemical composition of chiffon cake prepared by replacement wheat flour with oat flour and sucrose with erythritol.

Samples	C	M1	M2	M3
Moisture	27.69[d]	30.27[c]	31.50[b]	32.66[a]
Crude Protein	11.89[a]	11.91[a]	11.96[a]	11.99[a]
Fat	13.23[c]	14.0[b]	14.59[ab]	15.0[a]
Ash	1.28[c]	1.33[b]	1.37[b]	1.44[a]
Crude Fiber	1.24[d]	2.50[c]	3.17[b]	3.88[a]
Carbohydrates	72.19[a]	70.25[b]	69.14[c]	67.88[d]

Mean followed by different letters in the same column are significantly different by Duncan's multiple test ($P \leq 0.05$).

C = control sample M1= chiffon cakes prepared with 50% oat flour and 100% erythritol, M2= chiffon cakes prepared with 75% oat flour and 100% erythritol, M3= chiffon cakes prepared with 100% oat flour and 100% erythritol

Baking quality of chiffon cakes

Effect of replacement wheat flour with oat flour and sucrose with erythritol on chiffon cake weight, chiffon cake volume and specific volume were presented in **Table (4)** it could be revealed that, increasing oat flour levels in chiffon cake, weight gradually climbed while volume and specific volume dropped when compared to control cake. The greatest weight (360.0 g) was given by adding 100% oat flour to the chiffon cake sample compared to 342.6 g for control cake. Due of the high content of oat flour in the cake samples caused the molecules to coalesce and converge, which results in an increase in weight. Incorporating oat flour in chiffon cake had negative impact on volume and specific volume, where the highest values of 459 cm3 and 1.33 cm3/g were recorded by control chiffon cake. The gluten in wheat flour, which traps carbon dioxide and causes the volume to increase and take on a spongy texture, is what causes these outcomes. The gluten in wheat flour, which develops into a strong and extensive protein during baking, has the ability to retain gas in dough. This keeps the gas from escaping during baking and allows the dough to rise Akubor, and Ishiwu (2013).

Table 4. Baking quality of chiffon cake prepared by replacement wheat flour with oat flour and sucrose with erythritol.

Samples	Weight (g)	Volume (cm^3)	Specific volume (cm^3/g)
C	342.6	459	1.33
M1	350.7	450	1.28
M2	356.6	447	1.25
M3	360.0	440	1.22

C = control sample M1= chiffon cakes prepared with 50% oat flour and 100% erythritol, M2= chiffon cakes prepared with 75% oat flour and 100% erythritol, M3= chiffon cakes prepared with 100% oat flour and 100% erythritol

Glycemic index (GI) of chiffon cake samples

Post-meal blood sugar level A key indicator of the profile of insulin resistance and incidence of DM. Both the quantity and kind of carbohydrates consumed have an impact on the level the concept of GI was presented (Tahvonena et al., 2006), must take into consideration the significance of the latter in glucose response and ensuing insulin resistance and DM development. This naturally occurring biologic reaction is defined as the time course of glucose entrance into blood circulation after a healthy meal and its tendency to induce pancreatic β-cells to generate and secrete insulin.

Glycemic index is shown in **Figure 2.** The results indicated that GI of control chiffon cake had the highest levels compared to all chiffon cake samples. The GI were decreased as the levels of oat flour were increased and substituted sucrose with erythritol. Moreover, the lowest levels of these parameters of chiffon cakes prepared with 100% oat flour and 100% erythritol (68.61) followed by chiffon cakes prepared with 75% oat flour and 100% erythritol (69.50) compared to the control chiffon cake (80.20). The glycemic index values of cake samples were divided as medium glycemic index (55-70) (Oba et al., 2013). High dietary fiber oat flour may have an impact on the glycemic index score due to its basic role as hurdle in the digestion process (Gallagher, 2012) Dietary fiber increases viscosity, promotes prolonged repletion, decreases the absorption of macronutrients, affects and changes the glycemic index value, and lowers postprandial blood sugar levels. Consuming enough dietary fiber may help with managing and controlling blood glucose levels (Nisviyati, 2006). Additionally, adding fiber to the diet has a hypoglycemic impact because it slows down stomach emptying, glucose diffusion, and glucose absorption, which lowers the rise in blood sugar levels (Gropper et al., 2009).

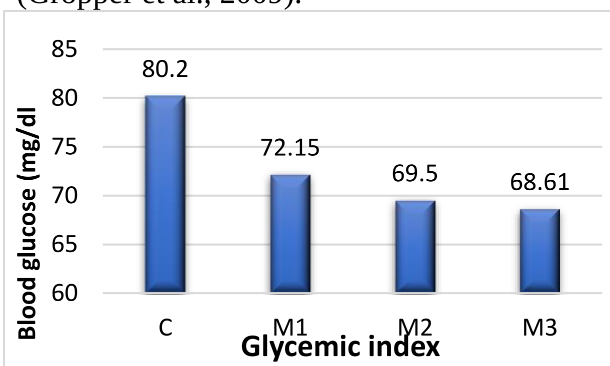


Figure 2. Glycemic index (GI) of chiffon cake samples

Growth inhibition of erythritol on cavity-causing bacteria

Polyols were regarded to be extremely useful in reducing the prevalence of tooth caries. In addition to preventing *Streptococcus* from growing, Erythritol was discovered to suppress the growth of all oral Streptococci investigated in this study. The presence of erythritol caused a 62% inhibition of *S. mutans* growth. The same erythritol concentrations also decreased the growth of *S. sobrinus* and *S. sanguinis* by 67 and 73%, respectively **(Table 5).**

Table 5. Growth inhibition of erythritol on cavity-causing bacteria

Cavity- causing bacteria	Percentage reduction (%)
S. mutans	62
S. sobrinus	67
S. sanguinis	73

The process by which erythritol prevents *S. mutans* from growing was investigated by Park et al. (2014). through the analyzing the glucosyltransferase and fructosyltransferase gene expression patterns in S. mutans when erythritol is present. These genes are engaged in the metabolism of sucrose by assisting in the polymerization of free glucose and fructose into glucans and fructans, which serve as an energy source and barrier against bacterial toxins and are involved in encouraging bacterial adhesion to tooth surfaces.

In the presence of the control and erythritol, the development of *S. mutans*, *S. sobrinus*, and S. sanguinis was monitored over the course of 24 hours and showed that erythritol significantly ($p \leq 0.05$) inhibited growth when compared with control. After 24 hours of incubation, the optical density of the culture reached the lowest for S. sanguinis, S. sobrinus and S. mutans in the presence of erythritol than control, demonstrating that erythritol is more effective at inhibiting the growth of Streptococcus strains. Additionally, our findings showed that for the majority of Streptococcus strains, the degree of inhibition and the inhibitory pattern vary (Figure 3).

Organoleptic properties of chiffon cake

The sensorial evaluation scores of chiffon cakes prepared by replacement wheat flour with oat flour and sucrose with erythritol were evaluated for crumb color, tenderness, moistness and sweetness in **(Table 6)**. As can be seen, replacement wheat flour with oat flour and sucrose with erythritol had a significant ($p \leq 0.05$) effect on all sensory attributes of the tested chiffon cake. Data show that control chiffon cake recorded the highest scores for crumb color, Tenderness, and sweetness. Meanwhile there was no significant difference between control and chiffon cakes prepared with 50 and 75% oat flour and 100% erythritol in crumb color. According to ANOVA, Tenderness were not significantly ($p \leq 0.05$) different in control and chiffon cakes prepared with 50% oat flour and 100% erythritol. Furthermore, it could be noticed that chiffon cakes control gave similar less scores moistness. While it could be noticed that chiffon cakes prepared with 50% oat flour and 100% erythritol was decreased in sweetness when compared with chiffon cake control, but was still acceptable. These data in accordance with the finding of Gao et al. (2016) who reported that the quality of food products impaired with the partial replacement of sugar.

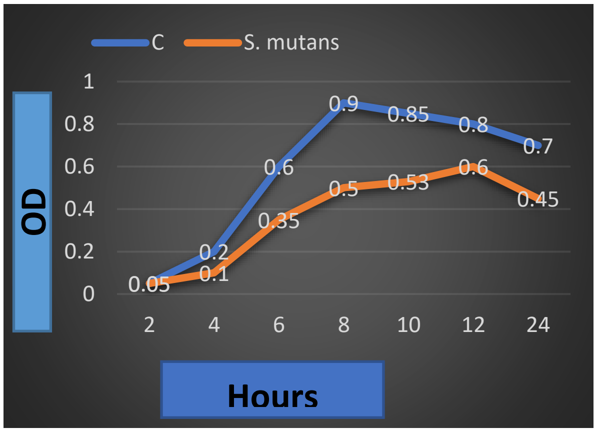
Conclusions

In conclusion, from the obtained results, it could be concluded that, adding oat flour with wheat flour can improve the nutritional characteristics, reduces the volume and specific volume of the cakes and however, oat flour cakes can be achieved with good acceptability by consumers., in addition to their suitable for diabetic and obesity. The use of erythritol and other similar biological sweeteners products is the best way to control dental caries in the future because erythritol is a new polyol and doesn't have a laxative effect. The current study has shown that using erythritol, as a natural sweetener, has a positive impact on producing healthy chiffon cake with a remarkably low glycemic index. This sweetener, in our opinion, can be used to create appropriate food samples with a low glycemic index.

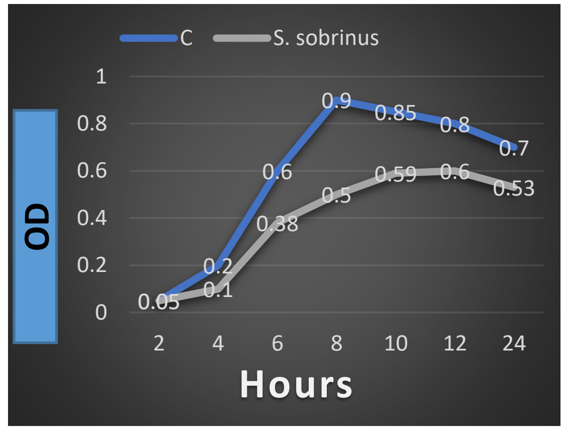
Acknowledgments (optional)

The author gratefully acknowledges the Department of Food Science and Technology, Faculty of Home Economics, Al-Azhar University, Tanta, Egypt for supporting some analysis in this research.

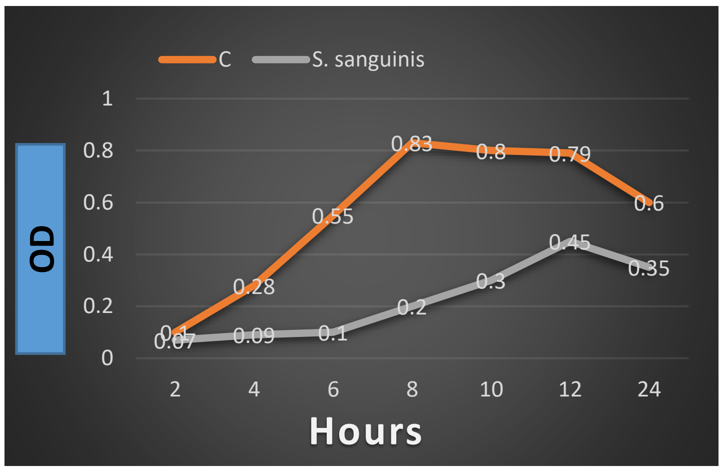
Conflicts of Interest/ Competing interest



(a) *S. mutans*, erythritol and control



(b) *S. sobrinus*, erythritol and control



(c) *S. sanguinis*, erythritol and control

Figure 3. Growth (600 nm) of *S. mutans, S. sobrinus* and *S. sanguinis* were evaluated over 24 hours in the presence of sucrose and erythritol.

Table 6. Organoleptic Properties of chiffon cake prepared by replacement wheat flour with oat flour and sucrose with erythritol.

Samples	Crumb Color (10)	Tenderness (10)	Moistness (10)	Sweetness (20)
C	8.41^{a}	9.0^{a}	8.0^{b}	19.0^{a}
M1	8.33^{a}	8.95^{a}	8.83^{ab}	15.0^{c}
M2	8.27^{a}	8.1^{b}	8.9^{ab}	18.72^{b}
M3	8.0^{ab}	8.05^{b}	9.0^{a}	18.87^{ab}

C = control sample M1= chiffon cakes prepared with 50% oat flour and 100% erythritol, M2= chiffon cakes prepared with 75% oat flour and 100% erythritol, M3= chiffon cakes prepared with 100% oat flour and 100% erythritol

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