ISSN: 0378-2700

Production of low-fat free-sugar ice cream using intensive sweeteners (sucralose and stevia).

By

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Summary

In this study, sucralose and *Stevia rebaudiana* were used as sucrose substitute, polydextrose as a bulking agent and sorbitol to control the freezing point. The treatments were: T1: control low -fat (2% fat), T2: control 2% fat + 2% maltodextrin , T3: 2% fat + 2% maltodextrin + sucralose, T4: 2% fat + 2% maltodextrin + sucralose + sorbitol, T5: 2% fat + 2% maltodextrin + stevia, T6: 2% fat + 2% maltodextrin + stevia + sorbitol.There was no obvious differences in the chemical composition of all treatments except T1 as it was less in TS. There was an increase in the acidity % when the sugar replaced by sucralose or stevia while there was no significance between the treatments. Addition of fat replacer (maltodextrin) and polydextrose and sorbitol lower the freezing point. The specific gravity of the mix was ranged between 1.10 to 1.16 gm/cm^3. The corresponding values of weight/ gallon in ice cream mixes were clearly related to the specific gravity of the ice cream mixes.

The viscosity of control T1 was the minimum, while in the other experimental samples it varied between 1513.33 to 1626.66 Cp due to the addition of maltodextrin and polydextrose. The overrun of the different treatments ranged between 24.82 to 39.28%. The highest was for control T1 and at last the stevia free sugar ice cream. The highest value of hardness was for T1 (control without any additions). Replacing sugar with stevia affected the hardness of the ice cream and it was higher than the other low -fat free sugar ice cream. The control T1 without any additives achieved the lowest degree in colour as it was low fat. Combination of polydextrose with maltodextrin as a bulking agent enhanced the colour of ice cream. At the first 15 min. the melting portion of T1 was higher than the other treatments,

The organoleptic scores revealed that T1 had the lowest scores. Addition of fat replacer to the other treatments improved the properties of ice cream. The TBC in the optimized low- fat free sugar ice cream was ranged from 3.7 to 5.8x 10^{3}cfu/g. The coliform, the psychrophilic bacteria and moulds & yeasts were absent. The reduction in caloric value in treatments T3, T4, T5 and T6 were 40.45, 35.57, 42.05 and 35.60%, respectively.

Key words: Low-fat ice cream - Low-calorie ice cream - Stevia - Polydextrose and Sorbitol – Maltodextrin, sucralose

INTRODUCTION

The awareness of consumers for healthier and functional foods has led to development of new technologies for manufacture of low caloric value products **(Akin *et al*., 2007, Soukoulis *et al*.,2009).** Frozen desserts in particular have the potential for the development of lower-fat, reduced or

ISSN: 0378-2700

free-sugar products which may led to increased sales.

Ice cream is one of the most served and loved desserts but it is high in fat content (10-14%) and sugar (30%). Therefore; formulating its low-fat and sugar free version will serve in good cause for reducing the extra-calorie intake and make it healthier. Removal of fat or partly removal of fat from the ice cream lowers the characteristics of the product by using fat replacers. Sugar has a major part in the structure of ice cream and its removal to prepare sugar free ice cream counts for some defects like adjustment in total solids and loss in freezing point depression. The prior can be compensated by using bulking agent like polydextrose and later by adding freezing point depressant like sorbitol **(Pinto and Dharalya,2014; Patil and Banerjee, 2017).**

Bulking agents like polydextrose impart creaminess, smoothness, improve texture and provide a mouthfeel and protection against temperature fluctuation. Sorbitol contains low glycemic index(GI). Low GI foods are important in dietary management as they allow slow movement of glucose into the blood resulting in very low rise to blood glucose and insulin levels. The uses of artificial sweeteners in food are very useful as it imparts sweetness without adding sugar. Artificial sweeteners considered safe. From these, sucralose as it is not digested by our body and it is 600 times sweetener than sugar **(Morlock and Prabha, 2007).** ***Stevia rebaudiana*** also is noncalorific value and high sweetener being about 300 times as sweet as sucrose **(Chalapalhi *et al*., 1997).** Polydextrose can be used as a bulking agent with these artificial sweeteners and sorbitol can be used to control the freezing point.

MATERIALS AND METHODS

Materials:

Fresh buffaloes' milk was obtained from the herd of Faculty of Agriculture, Moshtohor, Benha University, Qalubia, Egypt. Skimmed milk powder grade A was imported from USA and packed in 25Kg (lactose 53.3%, protein 34.0%, minerals 7.9%, fat 0.8% and moisture 3.8%). Fresh buffaloes cream (50-55% fat) and fresh skimmed milk used in this study were obtained from the Dairy Science Department, Faculty of Agriculture, Moshtohor, Benha University, Qalubia, Egypt. Sugar was obtained from local market, manufactured according to the Egyptian Standard Specification No358 for the year 2005. Carboxy methyl cellulose (CMC) was obtained from Mifad Co, Badr City, Cairo, Egypt. Vanilla was imported from china (CH3O) (OH) (C6H3Cho). Maltodextrin (MD) was obtained from aiochemica. Polydextrose used in this study was obtained from Dalya Foreign Trade Co. (Istanbul, Turkey). Sorbitol (C6H14O6) produced by Techno pharmchem, Bahdurarh (India) An ISO 9001: 2008 Certified Company. *Stevia rebaudiana* produced by Techno pharmchem, Bahdurarh (India) An ISO 9001: 2008 certified company. Sucralose (1,6 dichloro- 1.6 dideoxy – 5- fructo-furonosyl 4- choloro- 4 deoxy- Alpha- galactopranoside) was obtained from Tale & Lyle speciality sweeteners, U.K.

Methods

Methods of manufacture:

1- Preparation of the mixes and ice cream manufacture:

Ice cream mixes were prepared according to the method described by **Marshall and Arbuckle (1996)**. Skimmed milk powder was first mixed with sugar and CMC to generate a " dry mix". Fresh skim milk was preheated to 40°C, fresh cream was added, temperature was raised to 65°C and the " dry mix" was slowly added with gentle stirring. The mixture was heated to 80°C/ 5 min., followed by cooling to 4-5°C. Vanilla powder was added during cooling and aging at 5°C. The different mixes were aged for 24h whipped using ice cream

ISSN: 0378-2700

maker **Promag DS 15/18**. The ice cream was collected at an exit temperature of -5.5 °C, filled in 100 ml plastic cups, covered, hardened at -25°C for one day and stored at -18°C until analyzed. All ice cream treatments were prepared in three replicates.

2- Analytical methods and properties of ice cream mixes.

Total solids, Fat, Total protein content, Ash content and Titratable acidity, were determined according to methodology mentioned in **AOAC (2005**). Carbohydrate content was calculated by difference as follows: % Carbohydrates =% Total solids - % (fat + protein + ash). pH values of ice cream mixes and ice creams were measured using a digital laboratory pH meter (JENCO model 1671, USA) according to the method of **BSI (1989).**

3- Ice cream properties:

Overrun of ice cream samples was calculated by using the method given by **Arbuckle (1996).**

Colour parameter of ice cream samples was measured using a colourimeter Model (Hanter lab colour Flex). The *L**, *a** and *b** values were recorded, with *L** denoting lightness on a 0-100 score from black to white; *a**, red (+) or green (-); and *b**, yellow (+) or blue (-) as described by **Francis (1983).**

4- Physical properties:

The specific gravity of the ice cream mixes and ice cream was measured as described by **Marshall and Arbuckle (1996).** The weight per gallon (Kg) of ice cream mixes and the final ice creams were calculated according to **Marshall and Arbuckle (1996).** Freezing point was measured according to **Marshall *et al.*, (2003)**. The apparent viscosity (CP) of mix was measured using Brookfield measurements and was done at 5°C with a spindle No. #07 at 50 rpm and the reading recorded after 30Sec of spindle rotation to ensure a steady reading in 250 ml cup, approximately 24 hours after preparation of ice cream mixes, viscosity (centi poise). Hardness (N) of ice cream can be defined as the force required reaching a given deformation or the maximum load from first compression cycle. The hardness was measured by (Force measurement IMADA Texture Analyzer).Dairy Sci. Dep. Faculty of Agric. Benha Univ. Meltdown of resultant ice cream for each sample was estimated according to **Segall and Goff (2002)**. Ice cream samples were placed into wire mesh over a glass funnel fitted on conical flask at ambient temperature (28±1ºC). The time at which the first drop of ice cream dripped was noticed. Then, the melted ice cream was weighed every 15 minutes.

5- Sensory evaluation of ice cream:

Samples of ice cream after 24hr. of hardening at -18ºC were judged by 12 panelists of the staff members of Dairy Department, Faculty of Agriculture, Moshtohor, BenhaUniversity. The ice cream was tempered to -15°C to -12°C before sensory evaluation.Scoring was carried out according to **Khalil and Blassy (2019)** for flavour (50 points), body and texture (30 points), melting rate (10 points) and colour (10 points).

6- Microbiological analysis

Total bacterial counts of ice cream were enumerated as described by **IDF (1991).** Psychrophilic bacterial counts of ice cream were measured as reported by the **Difco (1984)**, Yeast and Mould counts were counted as described by **IDF (1990)** and Colifrom bacteria were detected as described by the **APHA (1992).**

7- Caloric value

Caloric value of prepared ice cream mixes was calculated according to **Marshall and Arbuckle (1996)** as follows: fat 8.79, carbohydrate 3.87 and protein 4.27.

8- Statistical analysis:

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Statistical analysis of variance of the obtained data were done using the general linear models procedure system **SAS (2006).**

EXPERIMENTAL

From the previous studies it was concluded that 2% maltodextrin was the best fat replacer in making low-fat ice cream (**Abdou *et al*., 2019**). Thus, it was used in preparing the low-fat free sugar ice cream in this work.

Preliminary experiments indicated that the level of sucralose which gave an equivalent sweetness to the 16% sucrose is 0.0266%. While the level of *Stevia rebaudiana* which gave the same sweetness is 0.0533%.Six treatments were used for preparing the ice mixes with a basic formula consisting of:

Fat, 2% - MSNF 11% , Sugar 16% , Stabilizer 0.4% and Vanilla 0.08%

Sucrose was used as sweetener in the controls. The sweetness of sucralose in the final product was adjusted taken the relative sweetness as (600), sorbitol as (0.5) and stevia as (300) into account.

The required quantity of sucralose was mixed with about 50 times its weight (w/w) of distilled water and mixed thoroughly and added to the mixture just before freezing.

The prepared mixes were tested for chemical composition and its properties and the resultant ice cream was tested for its properties, microbiological quality and sensory evaluated.

Caloric value was estimated.

Experimental was repeated three times and each test was done in duplicate and the data obtained was statistically analysed at ***P<0.05***.

The different treatments were:

T1: 2% fat - T2: 2% fat + 2% maltodextrin - T3: 2% fat + 2% maltodextrin + sucralose

T4: 2% fat + 2% maltodextrin + sucralose + sorbitol - T5: 2% fat + 2% maltodextrin + stevia

T6: 2% fat + 2% maltodextrin + stevia+ sorbitol

RESULTS AND DISCUSSION

Chemical composition of the different mixes

Table (2) show the average composition of various recipes. The total solids (T.S) in the mixes were 32.82, 34.61, 34.67, 34.40, 34.25 and 34.33% in T1, T2, T3, T4, T5 and T6 respectively. As expected, the total solids was the lowest in T1 (control) as the ice mix was low fat without addition of fat replacer. While there was a marginal difference between the other treatments. The total solids of all treatments are within the normal level of ice cream mixes given by **Arbuckle (1986)** and within limits that approved by the **Egyptian Legal Standard (1993).**

Table (1) The used Ingredients of different treatments and its composition

Ingredients	Treatments					
	T1	T2	T3	T4	T5	T6
Buffalos milk	307.72	307.72	307.72	307.72	307.72	307.72
Skimmed milk fresh	484.90	462.80	462.50	462.60	462.10	462.20
Skimmed milk powder	42.57	44.67	44.70	44.70	44.70	44.70
Sugar	160	160	-	-	-	-
CMC	4	4	4	4	4	4

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Vanilla	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**	**0.8**
Polydextrose	**-**	**-**	**160**	**130**	**160**	**130**
Maltodextrin	**-**	**20**	**20**	**20**	**20**	**20**
Sucralose	**-**	**-**	**0.266**	**0.242**	**-**	**-**
Stevia	**-**	**-**	**-**	**-**	**0.64**	**0.58**
Sorbitol	**-**	**-**	**-**	**30**	**-**	**30**
Total	**1000**	**1000**	**1000**	**1000**	**1000**	**1000**

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) -- T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol- T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

The fat content in all treatments was almost the same that there were no significant differences. This was attributed to that fat was standardized to 2% in all mixes. The results agree with **Khan *et al*., (2018),** as par the Indian standard (FSSAI), the fat content in low fat ice cream should not be more than 2.5 %.

The protein content in the mixes ranged from 4.53 to 4.71%. This is within that reported by many workers **(Abdou *et al*., (1996) ; Awad *et al.*, 2012 and Khan *et al.*, 2018).** It is clear from the results that the protein contents almost the same in all recipes. This is attributed to that the MSNT is the same in all recipes. The total ash content was almost the same and ranged from 1.03 to 1.05%.

The carbohydrate (CHO) based of bulking agents such as maltodextrin (used as a fat replacer) and polydextrose which is currently used in low calorie formulations (1Kcal/g) because they produce minimal negative effects on ice cream production, shelf life and price **(Roland *et al*., 1999).**

The carbohydrates ranged from 25.28 to 27.05% in all treatments. It was the lowest in the control1 (T1) and this was expected as it was without fat replacer (maltodextrin). It was observed that using polydextrose and maltodextrin as a bulking agents in low fat free sugar ice cream did not affect the composition of the mixtures except T1 as it is a control without the addition of maltodextrin. The previous results are in accordance with many previous results. **Abdou *et al*., (1996)** also reported no significant effect on composition of mixtures when sucrose was replaced with combination of polydextrose and aspartame. **Pinto and Dharaiya (2014)** also reported the same results and they attributed the marginal decrease in the TS to the moisture content of the dry matter of the mixtures.

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Table (2) Effect of using sucralose and stevia as a sweeteners on the chemical composition of low-fat free-sugar ice cream mixes (g/100g)

Treatments	T.S%	Fat%	Protein%	Ash%	CHO%
T1	32.82^{B}	1.96^{A}	4.53^{A}	1.04^{A}	25.28^{B}
T2	34.61^{A}	2.23^{A}	4.69^{A}	1.05 ^{A}	26.60^{A}
T3	34.67^{A}	2.03^{A}	4.55^{A}	1.03 ^{A}	27.05^{A}
T4	34.40^{A}	2.00 ^{A}	4.68^{A}	1.05 ^{A}	26.67^{A}
T5	34.25^{A}	1.98 ^{A}	4.71^{A}	1.05 ^{A}	26. 50^{A}
T6	34.33^{A}	2.00 ^{A}	4.70^{A}	1.05 ^{A}	26.58^{A}

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

Acidity% and pH value

Table (3) shows the acidity % and pH value of the different mixes. The acidity% was 0.17,0.17, 0.18, 0.18, 0.19 and 0.19% in T1, T2, T3, T4, T5 and T6, respectively. There was significant increase in the acidity when the sucrose was replaced by sucralose or stevia and bulk agents which agree with the results of **Abd El- Ghany, (2008)** who found that the acidity increased by the sugar replacing. However **Abdou *et al.*, (1996)** stated that there were no differences observed in the percentage of the acidity of blends as it recorded in average 0.21%. **Arbuckle, (1986)** mentioned that the normal acidity of mix varies with the percentage of MSNF it contains. He added that

the acidity is related to the composition of the mix.

Data in the same table recorded the pH values of the different treatments which ranged from 6.47 and 6.58. Results revealed that there were no obvious differences between the treatments.

Ozdemir *et al.* (2015) reported that free sugar ice cream samples containing stevia had pH values around 6.5 and 6.62. The results are within the range given by many workers. **Arbuckle, (1986)** mentioned that while pH is related, in part,

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to the milk solids not fat content, normal mix pH is about 6.3.

Physical properties of the mixes

Freezing point

The freezing point depression is a critical parameter in ice cream production as it influences the initial mean range and the thermodynamic instability of the formed ice crystals which leads to their gradual growth **(Hartel, 2001).** The freezing point in table (3) was -2.5, -3.30, -3.70, -3.83, -3.60 and -3.86°C in T1, T2, T3, T4, T5 and T6, successively. Addition of fat replacer (maltodextrin) lowers the freezing point. With adding of bulking agents to free sugar treatments as polydextrose and sorbitol, the frozen dessert would clearly change its behavior. Using polydextrose and maltodextrin in ice cream mixes instead of sucrose decreased the freezing point of the mixes which may be due to the higher content of ash than sucrose. Therefore, bulking agents is required to affect the contribution of sweetener to total solids and a freezing point depressant, required to minimize the change in freezing profile caused by removal of sucrose **(Tharp, 1991).** The results consisted with **Abdou *et al*., (1996)** and **Pinto and Dharaiya (2014)**. Also the freezing point of the sucrose mixes is within the level given by **Arbuckle, (1986)** who mentioned that initial freezing point of the average ice cream mix is -2.8 to -2.2°C.

Table (3) Effect of using sucralose and stevia as a sweeteners of low-fat free-sugar ice cream mixes on acidity and pH

Treatments	TitratableAcidity%	pH value
T1	0.17^{B}	6.47^{A}
T2	0.17^{B}	6.54^{A}
T3	0.18^{A}	6.50^{A}
T4	0.18^{A}	6.58^{A}
T5	0.18^{A}	6.49^{A}
T6	0.19^{A}	6.54^{A}

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

Table (4) Effect of using sucralose and stevia as a sweeteners of low-fat free-sugar ice cream mixes on Freezing Point °C specific gravity, weight/gallon and viscosity

Treatments	Freezing Point °C	Specific Gravity g/ml	Weight/gl (Kg)	Viscosity Cp
T1	-2.50^{A}	1.13^{A}	4.28^{A}	960.00^{B}
T2	-3.30^{B}	1.13^{A}	4.26^{A}	1513.33
T3	-3.70^{c}	1.16^{A}	4.40^{A}	1626.66
T4	-3.83^{c}	1.14^{A}	4.33^{A}	1613.33
T5	-3.60^{c}	1.11^{A}	4.22^{A}	1546.66
T6	-3.86^{c}	1.10^{A}	4.16^{A}	1527.66

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2%

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maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

Specific gravity and weight /gallon of the mixes

Specific gravity and weight /gallon are shown in Table (4). Non-significant (***P<0.05***) variations can be observed between the different mixes. It was ranged from 1.10 to 1.16 gm/ml. The specific gravity of sucralose mixes is higher than the control mixes with sucrose (T1 and T2) while the treatments containing stevia T5 and T6 were lower. The results are within the figure given by **Arbuckle, (1986)** as he mentioned that the specific gravity of the mix varyfrom 1.054 to 1.232 gm/ml. The results are in accordance with **Abdou *et al*., (1996)** and **Abd El-Ghany, (2008). Salama, (2004)** reported that using stevia as replacer to sucrose decreases the specific gravity of the mix which is in par with this current research.

The corresponding values of weight per gallon in kilogram of ice mixes were clearly related to the specific gravity of the ice cream mixes.

Viscosity (Cp)

Viscosity has been considered an important property of ice cream mixtures and up to a certain extent; it seems essential fact proper whipping and retention of air cells. The viscosity of mixture is also affected by the composition, especially, fat, protein and stabilizer and the quality of ingredients used. Hence, the aged mixtures were subjected to viscosity test.

Table (4) recorded the results of viscosity of various mixes. The viscosity of control (T1) was the minimum that is 960 Cp, while in the other experimental samples it varied between 1513.33 to 1626.66 Cp. It was observed that (T1) which was without any additions was the lowest, while addition of maltodextrin in (T2) increased the viscosity to be 1513 Cp.Using maltodextrin and polydextrose had a significant effect on viscosity of the low calorie (free sugar) mixes. This result may be due to the density increasing property of maltodextrin and polydextrose. This is in accordance with **Guzeler *et al*., (2011). Tharp, (1991)** explained that the structure of maltodextrin is such that it has water controlling function in addition to providing bulk. In that respect, their use as partial replacement of sugar, solids can supplement the role of stabilizer in controlling the elevated water levels in calorie reduced frozen desserts.

Abdou *et al*., (1996) observed only slight increase in the viscosity of low calorie ice cream mixture containing polydextrose which was non significant. **Alizadeh *et al*.,(2014)** reported that

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the stevia addition decreased the viscosity of ice cream mixes. **Ozdemir *et al*., (2015)** found that the viscosity of samples containing sugar alcohols and (HFCS) were lower than that of sucrose. **Arbuckle, (1986)** mentioned that the basic viscosity of ice cream mix may range from 50 to 300 Cp. The viscosity is influenced more by the fat and stabilizer than by the other constituents. Moreover, it can suggest that the total replacement of sugar with sucralose or stevia and its percentage in each formulation is too little to have significant effect on the viscosity of the mix.

Properties of the resultant low fat free sugar ice cream

Overrun

The overrun of the ice cream is an important property since it directly has relation with yield and profit. It also affects the body, texture and palatability of the final product.

Table (5) shows the overrun % of the different treatments as it ranged between 24.82 to 39.28%. These values are lower than the general literature value of (80-100%) **(Ozdemir *et al*., 2008 and Abd El-Ghany, 2008)**. A possible reason for getting a lower overrun value is due to the inconsistency during the whipping process **(Chang and Hartel, 2002**). Reports also commented that it is too difficult to get an overrun value in ice cream produced by a batch type freezer **(Guven *et al*., 2003; Dervisoglu *et al*., 2005)**.

It was observed that the highest overrun was for T1 then T2 which containing maltodextrin which was the second due to the maltodextrin which lowers the overrun as discussed before **(Abdou *et al*., 2019)**. The other treatments (free sugar ice cream showed low overrun than T1 and T2. Literature also established that increased sugar concentration has important role in high overrun **(Akin *et al*.,**

Table (5) Effect of using sucralose and stevia as a sweeteners of low-fat free-sugar ice cream on overrun, Specific gravity, weight/gallon, and Hardness.

Treatments	Overrun%	Specific Gravity g/ml	Weight/gl (Kg)	Hardness (N)
T1	39.28^{A}	0.68^{C}	2.57^{C}	13.1^{A}
T2	37.36^{B}	0.73^{BC}	2.76^{BC}	7.4^{D}
T3	27.85^{C}	0.81^{AB}	3.09^{AB}	8.7^{C}
T4	29.68^{BC}	0.81^{AB}	3.06^{AB}	11.9^{B}
T5	24.82^{C}	0.82^{A}	3.12^{A}	11.9^{B}

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T6	**25.30^{C}**	**0.80 $^{A B}$**	**3.04^{B}**	**12.4^{A}**

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

2007). Schmidit *et al*., (1993) in their study also indicated that carbohydrates like polydextrose and maltodextrin, used in the formulated ice cream under this study has led to decrease overrun and this study was further supported by **Jamshidi *et al*., (2012).**

Specific gravity and weight per gallon of the ice cream

Table (5) indicated that T1 had a slight low specific gravity than T2. The other treatments in which the sucrose substituted with sucralose or stevia also showed no observed differences and they were higher than the control.

The corresponding values of weight per gallon took the same trend as the specific gravity. The results are in accordance with **Abdou *et al*., (1996).**

Hardness

Hardness of the product at the temperature at which it has the optimum consistency is for dipping or scooping an important consideration. Hardness is affected by several factors: principally melting point, total solids, overrun amount and type of stabilizer ***etc***. Freezing and melting point decrease as the concentration of water-soluble substances increases.

Table (5) depicts the average hardness values of ice cream samples which ranged from 7.4 to 13.1. N. Data reveal that T1 control without any additions was the hardest of all samples. Addition of maltodextrin to all other treatments as a fat replacer reduced the hardness with different levels. Incorporation of maltodextrin to ice cream mixes decreased the hardness which may be due to that the excess of carbohydrate material can interfere with structure development and partly prevents strand reducing formation and protein-protein interaction, thereby reducing the strengthen of the resulting product. This suggests that it is the protein network, which is more important to the product structure **(Rawson and Marshall, 1997).** The results are in accordance with **Abd El-Aty and El-Nagar, (2004).**

Concerning T5 and T6, it was observed that replacing sugar with stevia affected the hardness of the ice cream. This may be due to the microstructure change, mainely phase volume,

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ice crystal size, and fat stability in the ice cream **(Muse and Hartel, 2004).** This finding cleared that the replacement and concentration of stevia affect the total soluble solids, determining amount of ice formation with high water content, ice crystal is packed closer to each other and a longer force is required to be applied to the surface of the ice cream that is being categorized as hard **(Muse, 2003).**

Colour

The colour of vanilla ice cream should be attractive, uniform, pleasing, and typical of the flavour stated on the label. The shade of colour must reasonably resemble the natural colour of cream, being neither too pale nor too rival. Colour criticisms are generally resisted for vanilla- falvoured products.

The colour values (*L**, *a**, *b**) of different samples are summarized in Table (6). The *"L*"*values determine the black (0) to white (100) colour. The *"L*"* value was ranged from 82.82 to 85.41. T1 (control without any additives) gained the lowest degree as it was low fat (2.0%). Addition of fat replacer (maltodextrin) raised the *"L*"* value of all samples. This result was consisted with **Roland *et al*., (1999)** who observed that maltodextrin low-fat sample was as white as 10% fat ice cream. They observed also that combination of polydextrose with maltodextrin, as a bulking agent in this study could enhance the colour of ice cream. The "*a**" value is an indication of red (positive values) to green (negative values) colour. As shown, all "*a**" values are negative which indicate that all treatments showed more green colour than red colour. Addition of maltodextrin as a fat replacer resulted in a reduction in the green colour than red colour compared to control. The results of *"b*"* value are comparing yellow (positive values) to blue (negative values). It is clear that all the treatments with sucralose and stevia increased yellowish colour of ice cream because polydextrose samples was yellow *b** values.

Melting resistance

It is well established that ice cream with superior melting resistance may be preferred by the consumers as well as from the viewpoint of convenience in storage and serving. Meltdown is an important property of ice cream affecting its sensory quality. It is important from at least two main points of view: eye appeal and mouth feel which may differ according to the type of ice cream (**Flack, 1988**). It is also important that the ice cream is not too hard or should not melt quickly. The melted product flows readily and forms a homogenous fluid with the appearance of unfrozen mixture and with little foam **(Marshall *et al*., 2003).**

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Table (6) shows the data of the melting resistance of the resultant ice cream for various recipes after 15, 30, 45 and 60 minutes. It was found that at the first 15minutes the melting portion of T1 (control without any additions) was higher than other treatments, came after T2 which containing sucrose and maltodextrin. This decrease in the melting portion may be due to the addition of maltodextrin. Treatments T3, T4, T5 and T6 were more resistant in melting than T1 and T2. This was attributed to the sugar substitution by polydextrose or polydextrose + sorbitol and sucralose or stevia which caused a decrease in the freezing point of the ice creams for less than sucrose **(Kach, 1992) and (Abdou *et al*., 1996).** As the time progressed, it can be seen clearly that the melting rates were stable with stevia and sucralose; the melting portion after 60 min reached to 99.50, 98.80, 99.64, 99.86, 99.89 and 98.87% for T1, T2, T3, T4,T5 and T6, in the same order.

Table (6) Effect of using sucralose and stevia as a sweeteners of low-fat free-sugar ice cream on colour and melting resistance

Properties		Treatments					
		T1	T2	T3	T4	T5	T6
Colour	*L**	82.82	84.40	85.41	84.39	84.07	83.09
	*a**	-3.07	-2.73	-2.47	-2.56	-2. 30	-2.49
	*b**	13.57	12.63	18.44	18.24	17.11	15.98
Melting Resistance	15min	34.70 Ad	27.07 Bd	25.77 Ed	26.46 ECd	19.19 Ca	18.09 Dd
	30min	53.45 Ac	52.28 Bc	44.17 Ec	47.82 BCc	47.80 Cc	59.20 Dc
	45min	78.70 Ab	77.63 Bb	71.17 Eb	79.18 BCb	83.97 Cb	70.43 Db
	60min	99.50 Aa	98.80 Ba	99.64 Ea	99.86 BCa	99.89 Ca	98.87 Da

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

Moreover, **Muse and Hartel (2004)** observed that type and amount of sweetener affects the melting rate of ice cream. Also, it was recorded by many investigators that the ingredients of the mix affect greatly on the melt resistance of the resultant ice cream through its effect on the freezing point and viscosity of the mix **(Abdou *et al*., 1996; Mahran *et al*., 2001 and Abdalla, 2003).**

Sensory evaluation low-fat free-sugar ice cream

The fate of any food product has always depends on the acceptance of the product by the consumers. The quality of the ice cream judged

ISSN: 0378-2700

by consumers depend on its flavour, body and texture, melting behavior and colour and appearance. The ice cream samples were adjudged by panels of 15 judges using the scores recommended by **Khalil and Blassy (2019**).

The frozen ice creams were served in shilled in plastic cups at - 12 to -14°C. The results represent in Table (7) reveal that partly removal of fat (T1) causes body and textural problems ***e.g.*** coarseness and iceness, crumbly body, shrinkage and flavour defects **(Berger,1990; Marshall and Arbuckle 1996)**. Samples with reduced fat and sugar showed a higher intensity of bitter taste and firmness and lower intensity of creaminess **(Cadena *et al*., 2012).** Addition of maltodextrin (2%) as a fat replacer (T2) increased the sensory scores with respect to flavour, body and texture, colour and total acceptability. This result consists with **Verma, (2002) and Abdou *et al*., (2019).**Hense, maltodextrin effectively can work as fat replacer in low-fat sugar free ice cream. **Abdou *et al*., (1996)** did not observe any effect of substitution of milk fat with hydrogenated palm kernel oil and polydextrose and aspartame in place of sucrose on organoleptic properties of ice cream .**Pinto and Dharaiya (2014)** reported that maltodextrin have a slightly masking effect on the milk flavour which otherwise is imparted by polydextrose.

Table (7) Effect of using sucralose and stevia as a sweeteners on the sensory evaluation of low-fat free-sugar ice cream

Treatments	Flavour (50)	Body& Texture(30)	Melting Resistance(10)	Color(10)	Total acceptability(100)
T1	42^{C}	23^{D}	7^{B}	8^{B}	80^{D}
T2	44^{B}	25^{C}	8^{AB}	10^{A}	87^{C}
T3	46^{A}	28^{A}	9^{A}	9^{A}	92^{A}
T4	45^{AB}	28^{A}	9^{A}	9^{A}	91^{B}
T5	47^{A}	27^{B}	9^{A}	9^{A}	92^{A}
T6	44^{B}	28^{A}	9^{A}	9^{A}	90^{B}

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

In this study low fat sugar free ice cream was prepared using different sweeteners: sucralose and stevia with bulking agent of maltodextrin as fat replacer and polydextrose as bulking agent or polydextrose+ sorbitol using sucralose ((T3 and T4) and (T5 and T6)

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with stevia. With using sucralose and sorbitol the flavour and taste were enhanced. The prepared ice cream in consumption was not differentiated by any panelist as sugar free ice cream containing artificial sweetener. The artificial aftertaste was effectively masked by the flavour. Thus, treatment T3 and T5 gained the highest scores.

Polydextrose is claimed to retain creaminess and impart the qualities of smoothness, appropriate texture and mouthfeel. Similar results were obtained by **Pinto and Dharaiya (2014).** Results also are in accordance with **(Jana *et al*., 1994).** Concerning T5 and T6, the stevia was used for substituting sucrose in preparing low fat free sugar ice cream. It was found that addition of stevia to the mix has affected some properties of the mix and the resultant ice cream. The results reveal that the stevia mix was more viscous than the control(T1) containing sugar. Usage of stevia in ice cream affects the hardness and it lower the melting rate and it cause higher sustainability in the mouth. Therefore, stevia can be used as a sugar substitute in formulating ice cream for the health conscious market due to the benefits of stevia provides.

The results agree with **Pon *et al*., (2015).** However**, Yoghiraj *et al*., (2014)** found that addition of stevia improved sweetness, colour, appearance and texture. **Sivakumar, (2017)** reported the same observation.

Moreover the sweetening power and persistence of sweet taste by stevioside are affected by several factors such as concentration, ingredients and temperature of ice cream. The bitter aftertaste is a major problem associated with many sweeteners which limit their use. On the otherwise, sucrose has many disadvantages due to its high glycemic index which facilitate development of many metabolic diseases such as diabetic syndrome and obesity. Thus it seems reasonable to use natural sweeteners such as stevia in formulation of caloric foods like low fat free sugar ice cream despite some sensory limitation especially it was added with a very low level.

The overall acceptability score for different treatments were 80, 87, 92, 91, 92 and 90 for T1, T2, T3, T4, T5 and T6, respectively. The lowest scores was for (T1 control without any addition). T3 and T5 gained the highest scores (containing sucralose and stevia) while, addition of sorbitol to these sweeteners affects slightly the overall acceptability. However, **Khan *et al*., (2018)** reported that addition of sorbitolwith artificial sweeteners (sucralose) effectively masked the after taste of the artificial sweetener; hence they are effective in making

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low fat sugar free ice cream**.** Also, **Specter and Sister (1994)** and **Abdou *et al*., (1996)** showed no significant differences in organoleptic properties between frozen dessert made with sucrose and alternative sweeteners.

Alizadeh *et al*., (2014) concluded that application of stevia as a natural sweetener has a positive impact on producing an ice cream with remarkably low calorie and glycemic index without imparting effect on the properties of the ice creams.

Microbiological quality

Ice cream is a good media for microbial growth due to high nutrient value, almost neutral pH value (pH 6-7) and long storage duration of ice cream. However, pasteurization, freezing and hardening steps in the production can eliminate most of the microbiological hazards. Heating (80°C/5min) can destroy almost all pathogenic bacteria in the milk.

The subsequent process that subjects the mixtures to freezing temperature can also inhibit the growth of any remaining flora. Also, heat treatments of the blends can destroy most of the specific pathogens that pose risk to public healthier. The total plate count in the optimized low- fat free sugar ice cream was enumerated to be ranged from 3.70 to 5.43 x10^3cfu/g Table (8). The permissible standard for TPC as laid down in FSSAI for ice cream is 2x10^5cfu/g. The yeast and mould in the optimized low -fat free sugar ice cream were absent. The coliform count in the optimized low-fat free sugar ice cream and psychrophilic bacteria were not detected in all treatments of low-fat free-sugar ice cream. The results are in accordance with **(Khan *et al*., (2018).** Moreover, the report of microbial analysis conveys that ice cream products were processed, packed and stored under strict hygienic condition without any contamination.

Table (8) Effect of using sucralose and stevia as a sweetener on total count of low-fat free-sugar ice cream

Properties	Treatments					
	T1	T2	T3	T4	T5	T6
Total count (x10^3 cfu/gm)	5.43^{A}	4.30^{BC}	3.70^{C}	4.80^{B}	4.33^{BC}	4.30^{BC}

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol
T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol
*Means with the same column with the same superscript are non-significantly different (***P <0.05***).

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Caloric value

Ice cream considered an excellent source of food energy. It is a rich source of fat, protein and carbohydrates contributes significantly towards calorific value. The average calorific value of ice cream is approximately 200 kcal/100g.

Table (9) shows the caloric value of various treatments of low fat free sugar ice cream. The mean values were 134.49, 142.92, 80.09, 86.67, 77.95 and 86.62 kcal/100g for T1, T2, T3, T4, T5 and T6 respectively. It was revealed that T2 was higher in caloric value than T1 due to the addition of maltodextrin. In T3 and T5 the reduction was 40.45 and 42.04 % due to the replacement of sucralose and stevia instead of sucrose. While the reduction in T4 and T6 was somewhat lower due to the addition of sorbitol (contribute 2.6 kcal/g) as a bulking agent with the polydextrose (contribute 1 kcal/g) as the reduction was 35.56 and 35.59%, successively.

Khan *et al*., (2018) gave the calorific value of prepared low-fat free sugar ice cream to be 116.74 kcal/100g much lower than the average calorific value of ice cream.

Table (9) Effect of using sucralose and stevia as a sweeteners on caloric value of low fat free sugar ice cream

Properties	Treatments					
	T1	T2	T3	T4	T5	T6
Caloric value Kcal/100g	134.49	142.92	80.09	86.67	77.95	86.62
% of change in caloric value	-	+6.26	- 40.45	-35.56	-42.04	-35.59

T1: control 1 (low fat 2 %) - T2: control 2 (2% fat+2 % maltodextrin) - T3: 2% fat+ 2% maltodextrin + sucralose - T4: 2% fat+ 2% maltodextrin + sucralose + sorbitol - T5: 2% fat+ 2% maltodextrin + Stevia - T6: 2% fat+ 2% Maltodextrin + Stevia + sorbitol

Sorbitol, sucralose and stevia effectively works as low- caloric sweeteners .On the other side, accumulative data elucidated a positive correlation between increased dietary GI, amount of calorie and risk for coronary heart disease **(Mahan and Escott-stump (2003).** Judging from the remarkable reduction in caloric value and GI of stevia-based ice creams (T5and T6), it was suggested that substitution of stevia with sugars brings new relatively healthy choice for food basket of families with high risk of life style related to diseases including DM (**Barbara *et al*., 2006; Katie and Kevin, 2010).**

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