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Production of Ice Cream by Using Soy Milk, Stevia and Isomalt

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ABSTRACT

Nowadays a great deal of attention has been focused on functional food products such as soy milk. However due to the rising incidence of diabetes and its known complications, the use of low calorie sweeteners is very important instead of sugar in food products. The purpose of this study was to investigate production of ice cream by using soy milk, stevia and isomalt. In this study the effect of substituting stevia and isomalt (the ratios of 30:70, 40:60 and 50:50 stevia to isomalt) was evaluated on chemical, physical and sensory properties of produced ice cream. The results showed that by increasing the substitution of isomalt with stevia, the amount of total solids, overrun and viscosity of mixture increased significantly in all samples ($p< 0.0001$),while have no significant effect on the amount of protein, pH, fat, acidity and solids nonfat samples. The results showed the flow behavior index (n) in all of the treatments were lower than 1 (between 0.51and 0.73), which indicates a shear thinning behavior of mixtures. Also viscosity of ice cream samples decreased with increasing shear rate (rpm) and since needs an initial stress and also works like a shear thinning fluid, so the fluid behavior is similar to Herschel Bulkley. Finally the best ratio was the ratio of 50:50 isomalt to stevia in terms of all properties. Finally, the results of this study showed that production of diet soy ice cream with desirable sensory properties is possible. Produced ice cream has a high nutritional value and low amount of energy and is suitable for those people with lactose intolerance, hypertension, obesity and diabetes.

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INTRODUCTION

Ice cream is a frozen dairy dessert that is popular around the world and its consumption is growing continuously. Moreover, ice cream is a nutritious and frozen product consists of milk, sweetener components, stabilizer and flavor [1,29,3,13]. Nowadays the consumption of dietetic and low calorie products containing sugar substitutes is common in most countries. In addition, due to loss of physical movement of people, and disadvantages of sugar and its correlation to certain health problems such as hypertension, cardiovascular diseases, tooth decay, obesity and increased blood sugar, low calorie substances have been a common part of people diets. Also due to ice cream is regarded as one of the most widely consumed products among all age groups, Stevia natural sweetener or low digestible carbohydrates such as polyols like isomalt can be replaced with sucrose in ice cream to reduce calorie and glycemic index and to prevent tooth corruption [11]. The excessive and single use of each sweetener is associated with health problems such as digestive disorders, tumor genesis and cancer. So, one of the best ways to reduce these risks is continuous use of sweeteners and taste intensifier so each sweetener is consumed in lower rate of its authorized limit [43].

Stevia is a natural non-nutritive herbal sweetener that has no calories because stevia glycosides do not have metabolism capability, so it can be said that this herb is zero in calorie [6]. Stevia is about 300 times sweeter than sugar and is more resistant in compare to changes in temperature, light and pH = 3-9. Also its color does not change as a result of cooking and it can tolerate up to 200 °C. It has constant taste and persistent sweet that can be maintained in all production stages and is not fermented in presence of bacteria .Therefore, it does not cause tooth decay[37,10].

Isomalt is an alcoholic low-calorie disaccharide that is extracted from natural sugar and has the same taste as sugar. Isomalt is non-absorbable and its energy value is 2kcal/g that equals to half of sugar. Its sweetening power is 45 to 50 per cent of sucrose (MC Nutt, 1997). Blood glucose and insulin levels stay low after receiving isomalt; therefore it is very suitable for people who have high blood sugar and need less energy [36]. Isomalt is

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the only bulky sweetener derived from sugar. Like sugar it has many functional implications as texturizer, thickener and bulking that is used in products such as ice cream.

Soy milk is an inexpensive source that is rich in vegetable protein. The most important health effects of soy milk are to reduce cholesterol and triglycerides, the risk of some types of cancer, blood pressure and atherosclerosis [3]. The most significant features of soy ice cream is that it has no cholesterol and it does not only enjoy a low rate of saturated fatty acids, but it contains beneficial unsaturated fatty acids. Consumption of soy ice cream instead of regular ice cream causes saturated fat intake reduction, and also an increase in soy protein intake [13,44]. In most soy ice cream formulations the amount of calorie is at least 77 percentage of calories in regular ice creams [22,23,3,13]. Soy ice cream is free from lactose, and has high digestibility. It can be a healthy alternative for cow's milk, especially for people who have lactose intolerance and cannot use regular ice cream. It also is suitable and recommended for people with diabetes [45,23,13].

Using sesame oil can be desirable in producing diet soy ice cream in order to improve nutritional properties, enhancing antioxidant capacity, reducing the amount of saturated fatty acids and beany flavor of soy milk. The main advantage of using sesame extract is that sesame flavor which is preferred compared to taste of soy milk [35]. The purpose of this study was to produce dietary soy ice cream by using different ratios of stevia to isomalt and to investigate physical, chemical and sensory properties of dietary soy ice cream in order to determine the best ratio of stevia to isomalt.

MATERIALS AND METHODS

In order to produce dietetic soy ice cream, soy milk and skim milk were used in ratio of 50 to 50 and stevia and isomalt to achieve appropriate formulation in 3 ratios (50:50, 60:40 and 70:30 isomalt to stevia) were substituted with sugar and all the samples were produced in three replications.

Materials were used in this observation included Pasteurized skim milk (milk factory Pak Ara Sanandaj), sterilized soy milk (ACE CANNING CORP made in Malaysia), nonfat dried milk (Arya Rama Tehran company), cream 30% fat, pasteurized and homogenized, stevia powder (with purity 99%, that is 300 times sweeter than sucrose which is Made in France, Takfa company, Tehran), isomalt powder (98% purity, and with content half sweetness of sucrose, made in Russia from Noosh Azmoon Shimi company, Tehran), carboxy methyl cellulose CMC (made in Denmark), palsgaard (made in Denmark), sesame oil and sesame extract. At first Soy milk and skim milk were tested in terms of fat, protein, dry matter and pH to ensure the accuracy of the results.

Production of ice cream:

All formulas were considered on the basis of 64.6% of milk (50% soy milk to 50% skim milk), sugar 14.6 % (Stevia and isomalt sweeteners with defined ratios that were completely replaced with sugar), dried milk 5.8 %, sesame oil 3.9 %, cream (30% fat) 10.5 %, palsgaard 0.48%, CMC 0.12 % and sesame extract 0.1 %.

During the production of ice cream mixture all the ingredients of ice cream including all types of dry and liquid ingredients of the formulation were determined based on a specific weight**.** Liquid ingredients (skim milk and soy milk, etc.) were mixed and heated up to 25 °C. Next, dry ingredients were slowly added and stirred to the liquid ingredients in order to prevent clumping. Adding must be terminated before the temperature reaches 40°C. After dissolving all powder ingredients, the temperature was brought to 45 °C so cream and oil that had been previously heated were gradually added to the mixture and stirred slowly [28,29,19,30].

The next step was homogenization and pasteurization. A two-stage homogenization was applied on ice cream mixture at temperature of 70 °C and at pressure of 150 atm. HTST pasteurization was performed in holding tubes at temperature of 80 to 82 °C for 25 seconds. Then the cooling process was performed on ice cream mixture immediately after pasteurization (with water) to below 5 °C [28,29,30]. Next stage was aging the mix that was performed in a special tank. The mixture was maintained in less than 5 °C for 8 hours in special aging tanks. Also at this time the ice cream mixture frequently and gently was stirred in the tank of aging. Heat-sensitive materials such as flavors and also sesame extract that were acceptable in terms of microbial in conditions of optimal and suitable were added at this stage [28,16,19]. After aging, the main stage in the production process of ice cream is freezing such as aeration, stirring and freezing the mixture of ice cream. When the ice cream mixture was pumped from special tanks of aging with temperatures around 5 °C or less into the freezer tank, it was aerated and frozen. Ice creams were frozen with overrun in this stage. At freezing stage, the temperature was about minus 30 °C, in 30-60 seconds, the pressure inside the tank was usually 5 atm and rotation speed of stirrer was 200 rpm. The output temperature of ice cream was minus 5 °C. Then product was sent to forming and packaging units and was filled in 50 grams disposable containers of plastic. Hardening of ice cream at special tunnels and at temperatures of -38 to -45 °C was performed in 20 minutes for all the samples. In the next step samples were kept in freezers with temperatures around -18 °C until the organoleptic test [28,29,19,30].

Chemical analysis:

Total solids, protein content, fat content, pH and acidity of samples were determined in accordance with AOAC methods [1,9].

Physical analysis:

Viscosity:

The viscosity was determined by a Brookfield viscometer. The measurement was taken after a period of samples aging (for 8 h at 4 °C) with spindle number 4, 42 rpm, at 14±1ºC (model DV-II+Pro, Brookfield engineering laboratories, Inc., Ma, USA) [28,3].

Overrun:

The overrun value was determined according to the method described by Whelan *et al*., [46].

Sensory Evaluation:

For sensory evaluation 15 staffs were selected form Asal Ice Cream Factory in Sanandaj. These people were considered as fully experienced and trained in taste in the factory among the other individuals. Sensory evaluation of ice cream included taste, odor, body/texture, colour and overall acceptability [16].

Statistical Analysis:

Variance analysis of results of physical and chemical tests of ice cream was performed three times using SAS9 software in a completely randomized one-way format. Also sensory evaluation samples results were analyzed by variance analysis using Minitab software and data average was compared with Duncan's multiple range tests to analyze significant differences between treatments. The curves and charts of results were drawn were drawn by Excel software.

RESULTS AND DISCUSSION

The impact of different levels of substituting isomalt and stevia on the amount of total solids of ice cream:

The examination of variance analysis results in chemical properties of samples (Table 1) indicate that different levels of substitution of stevia and isomalt have a significant effect ($p<0.0001$) on total solids content of the samples. So that with increasing levels of isomalt, the content of total solids of ice cream increases, too. Moreover, ice cream sample containing 50:50 ratio of stevia to isomalt has the highest amount of total solids in 95% assurance level and sample containing 70:30 ratio of stevia to isomalt, has the lowest amount of total solids. Because ratios of soy milk and skim milk are constant in all samples, the main altering factor of total solids is the ratios of stevia to isomalt. Because the isomalt has high molecular weight, it will enhance the total solids of ice cream mixture [28,16].

Isomalt is a bulky sweetener and acts as a texture thickener. As a result, according to that isomalt has only half sweetening power and calorie of sugar, a greater amount is consumed and causes total solids content increase [27].

The impact of different levels of substituting isomalt and stevia on the amount of solids non fat, fat, protein, pH and acidity of ice cream:

Results (Table1) show that different ratios of stevia and isomalt have no significant effect ($p>0.05$) on content of solids non fat, fat, protein, pH and acidity of the samples. So that with increasing levels of substituting stevia a significant difference is not observed in the content of solids non fat, fat, protein, pH and acidity because solids non fat (MSNF) contain lactose, proteins, minerals and water-soluble vitamins [34]. Also soy milk and skim milk are the same levels in all samples and because the only variable factor in these samples are sweeteners, so they do not have affect on solids non fat, fat, protein, pH and acidity.

Physical properties of ice cream samples:

The impact of different levels of substituting isomalt and stevia on the amount of overrun of ice cream:

The examination of variance analysis results in physical properties of samples (Table 1) indicates that the effect of different ratios of stevia and isomalt are quite significant ($p<0.0001$) on overrun of the samples. Moreover, ice cream samples containing 50:50 ratio of stevia to isomalt have the highest amount of overrun in 95% assurance level and indicates that with increasing levels of isomalt replacement the amount of overrun increases, too. Also the mount of overrun can be affected by different factors including type of ingredients of the mixture such as total solids, viscosity, sweeteners, etc [4].Also some of researchers have found that use of polyols leads to a significant increase in overrun ($p <0.05$) and a reduction in the average diameter of air cells [29,38]. Since the only variable factor is the type of sweetener, so changes observed in the overrun should be justified based on the changes of sugar substitution. Some of researchers claimed that there are significant relationships between overrun and viscosity, so sweeteners substitution have significant effect on the viscosity of the mixture .Also

changes observed in the overrun are associated with the mechanisms that have led to viscosity changes of mixture. Finally it can be concluded that increasing the total solids and viscosity cause an increase in overrun and because the samples containing 50% isomalt and 50% stevia have the most amount of bulky sweetener, as a result, they have the most total solids and viscosity. Also the more increase in viscosity, the overrun increases, too [38,39]. A number of other researchers claimed that alcoholic sugars may create foam, stability and sustainability in the mixture of ice cream through their impact on viscosity increase during the stirring and freezing process and can lead to forming, trapping and stabilizing the air cells [38,39].

Table 1: Variance analysis of the chemical and physical properties of ice cream samples containing different ratios of stevia to isomalt (mean ± standard deviation).

Properties	Ratios of stevia to isomalt 50:50	60:40	70:30	Mean-square
Total solids(%)	34.0965 ± 0.0016^{a}	31.2106 ± 0.0007^{b}	28.3749 ± 0.0022^{c}	24.55315826^{**}
Solids non fat(%)	11.5613 ± 0.0105^{a}	11.5632 ± 0.0068^{a}	11.5662 ± 0.0043^{a}	0.00001827^{ns}
Fat (%)	7.2733 ± 0.0208^{a}	7.2900 ± 0.0173^{a}	7.2833 ± 0.0058^{a}	0.000211^{ns}
Protein(%)	4.3384 ± 0.0001^{a}	4.338 ± 0.0003^{a}	4.3377 ± 0.0003^{a}	3.8111111^{ns}
Stevia (%)	0.0243 ± 0.0000^{c}	0.0292 ± 0.0000^{b}	0.034 ± 0.0000^{a}	0.00007057^{**}
Isomalt (%)	14.600 ± 0.0000^{a}	11.680 ± 0.0002^{b}	8.7603 ± 0.0002^{c}	25.57686406^{**}
pH	6.6533 ± 0.0025^{a}	6.658 ± 0.001^{a}	6.6566 ± 0.0056^{a}	0.00001733^{ns}
Acidity (%)	0.1703 ± 0.0011^{a}	0.1713 ± 0.0005^{a}	0.1720 ± 0.0010^{a}	0.0000021^{ns}
Overrun (%)	85.2465 ± 0.0029^{a}	78.0287 ± 0.0026^{b}	70.9401 ± 0.0081^{c}	153.5096970^{**}
Viscosity (Centi-Poise)	6273 ± 18.083^{a}	4390.336 ± 10.598^{b}	2738.33 ± 12.503^{c}	9383703.11^{**}

^{ns} and ** respectively non-significant ($p>0.05$) and significant ($p<0.0001$).

The numbers in each row with dissimilar words have significant difference according to Duncan's test ($p<0.0001$).

The numbers in each row with the same words don't have significant difference according to Duncan's test ($p> 0.05$).

Akin *et al*., (2007) reported that increasing inulin content leads to an increase in ice cream overrun due to transplantation with water molecules, forming three dimensional networks and trapping molecules inside the network and their immobility.

The impact of different levels of substituting isomalt and stevia on the amount of viscosity of ice cream:

Table (1) shows that the effect of different ratios of stevia and isomalt are quite significant ($p<0.0001$) on content of viscosity of the samples. Ice cream sample containing 50% isomalt and 50% stevia has the highest amount of overrun and indicates that with increasing levels of isomalt replacement, the amount of viscosity increases, too. Since the only variable factor is the type of sweetener, so changes observed in the viscosity should be justified based on the changes of sugar substitution [39]. Also because isomalt is a thickener of texture and a bulky sweetener and considering that it has half sweetening power and calorie of sugar (300 times more than sucrose) consequently, a greater amount of isomalt is consumed that leads to viscosity increase.

Bulky sweeteners cause viscosity increase in the mixture of ice cream [39]. Isomalt due to its high molecular weight keeps water molecules within itself; thus it leads to viscosity increase. Also the increase of total solids causes an increase in viscosity of the mixture .Because the total solids of sample containing 50% isomalt and 50% stevia is higher, consequently, they also contain the highest viscosity. In addition, the use of polyol sweeteners, leads to an increase in coefficient consistency and apparent viscosity. The most important factors in improving the viscosity of ice cream mixture are water holding capacity and degree of polymerization.Willingness of sweeteners to water absorption causes viscosity increase [21]. Isomalt is hygroscopic and can be linked to water, so it results in viscosity increase [29,38]. A number of researchers have found changing sugar type is effective on changing viscosity of mixture. Because of high hydrophilic properties and their solubility, most sugars produce very viscous solutions [18].

Soukoulis *et al*., [38] claimed that polyols have a positive effect on rheological properties of ice cream .Results show that hygroscopic attributes polyols have obvious explanation for trends observed in rheological properties.

A number of researchers reported that viscosity and overrun increase in ice cream is due to inulin content increase [4] Other investigators reported the effect of alternatives like inulin on increasing the amount of viscosity and sustainability of texture by forming complex with soluble proteins in milk and long and narrow filaments creation. This can be due to mutual effect of dietary fibers, ingredients and components of liquid of ice cream. Inulin is very hygroscopic and can be connected with water [17,4].

Bashir Hashim, [12] showed using date syrup causes an increase in viscosity of ice cream. Main sections of sugar in date syrup include reducing monosaccharide sugars and small amounts of sucrose. It seems with functional increase of date syrup compared to sucrose, hydrogen bonds increases and with free water mobility reduction, the viscosity increases in ice cream mixture.

Viscosity determination of ice cream:

In order to recognize the fluidity of ice cream, viscosity of samples were measured with spindle 4 and at speeds of 10 until 100 rpm and at 14 ±1 °C. The results showed the flow behavior index (n) in all of the treatments were lower than 1 (between 0.51and 0.73), which indicates a shear thinning behavior of mixtures. Because with soy milk substitution in ice cream, the amount of pseudoplastic (or shear thinning) increases; due to the presence of high amounts of fiber composition. Also viscosity of ice cream samples decreased with increasing shear rate (rpm) and since needs an initial stress and also works like a shear thinning fluid, so the fluid behavior is similar to Herschel Bulkley.

Soukoulis *et al*., and Gracas Pereira *et al*., concluded that presence of fiber in insoluble ingredients and also soy milk increase in ice cream formulation significantly causes an increase in viscosity, shear thinning behavior (pseudoplasticity) in ice cream that its reason is the increase of total solids and forming a network of hydrated cellulose and hemicelluloses. Also the flow behavior index (n) was obtained lower than 1(psuedoplasticity) that results of these researchers are aligned with the findings of this study.

Sensory properties of ice cream samples:

The impact of different levels of substituting isomalt and stevia on taste, odor, texture, color and overall acceptability of ice cream:

The examination of variance analysis results in sensory properties of samples indicate that different levels of substitution of stevia and isomalt have a significant effect ($p<0.0001$) on taste, flavor and aroma, texture and overall acceptability (Table 2). The results indicate that with increasing levels of stevia replacement the scores of taste, flavor and aroma, texture and overall acceptability decrease and and sample containing 50% stevia and 50% isomalt have the highest score of taste, flavor and aroma, texture and overall acceptability. Also, the sample containing 70% stevia and 30% isomalt have the lowest score of taste, flavor and aroma, texture and overall acceptability (Fig.1).

Because stevia has a bitter taste and a sharp flavor, increasing stevia level will decrease the taste and flavor of the ice cream. The results showed that ice cream with ratio of 70% stevia and 30% isomalt was very bitter in taste and odor and almost had a inconsistent texture compared to other samples and overall acceptance of them was not appropriate. Ice cream containing 60% stevia and 40 % isomalt was less bitter in taste and flavor, and also was more consistent and smoothness of its texture was better and its overall acceptance was rather better compared to sample containing 70% stevia and 30% isomalt. Also ice cream sample containing 50% stevia and 50% isomalt was good and favorable that had no bitterness in taste and flavor. Also it had quite favorable texture with proper consistency and smoothness. Its color was completely suitable and had a good overall acceptance that finally was considered as the best and the most desirable sample. Isomalt due to its high molecular weight keeps water molecules within itself; thus it leads to a proper texture formation in samples. Also, isomalt level increase causes an increase in texture consistency. Because isomalt is a sweetener, thickener, bulker that improves texture, causes appropriate texture. So, as isomalt increases, overall acceptance increases, too.

The impact of different levels of substituting isomalt and stevia on the color of ice cream:

Results show that different ratios of substituting stevia and isomalt have no significant effect ($p>0.05$) on color of the samples, there are not significant differences between all three samples containing 50%, 60% and 70% stevia (Table 2).Also soy milk and skim milk are the same levels in all samples and because the only variable factor in these samples are sweeteners, so they do not have affect on solid non fat, fat, protein, pH and acidity. Isomalt and stevia sweeteners do not provide negative impact on color. Because soy milk and skim milk are the same levels in all samples that are used at the ratios of 50% soy milk and 50% skim milk. For this reason, the color of ice creams has not changed and was the same at different levels of substituting stevia and isomalt.

Conclusion:

Results showed that different levels of isomalt and stevia have significant effect on content of total solids, overrun and viscosity of samples ($p< 0.0001$). While have no significant effect ($p>0.05$) on content of solids non fat, acidity, protein, fat and pH of samples. Moreover the results of sensory evaluation indicate that different levels of isomalt and stevia had significant effect ($p <0.0001$) on taste, odor, texture and overall acceptance of samples, While had no significant effect on color of samples .Finally sample containing 50% stevia and 50% isomalt was selected as the best and the most desirable sample in terms of chemical, physical and sensory

properties and at this sample had no bitterness in taste. This sample had appropriate texture and it had favorable overall acceptance.

Table 2: Variance analysis of sensory properties of Ice cream samples containing different ratios of stevia to isomalt (mean ± Standard deviation)

Properties	Ratios of stevia to isomalt 50:50	60:40	70:30	Mean-square
Taste	3.73 ± 0.457^{a}	2.33 ± 0.488^{b}	1.13 ± 0.351^{c}	25.400^{**}
Odor	4.00 ± 0.00^{a}	3.20 ± 0.414^{b}	2.53 ± 0.639^{c}	8.089^{**}
Texture	3.93 ± 0.258^{a}	3.13 ± 0.516^{b}	1.80 ± 0.414^{c}	17.422^{**}
Color	3.93 ± 0.258^{a}	3.93 ± 0.258^{a}	3.86 ± 0.351^{a}	0.0222^{ns}
Overall acceptability	3.86 ± 0.351^{a}	2.73 ± 0.457^{b}	1.46 ± 0.516^{c}	21.622**

^{ns} and ** respectively non-significant ($p>0.05$) and significant ($p<0.0001$).
The numbers in each row with the same words don't have significant difference according to Duncan's test ($p> 0.05$).

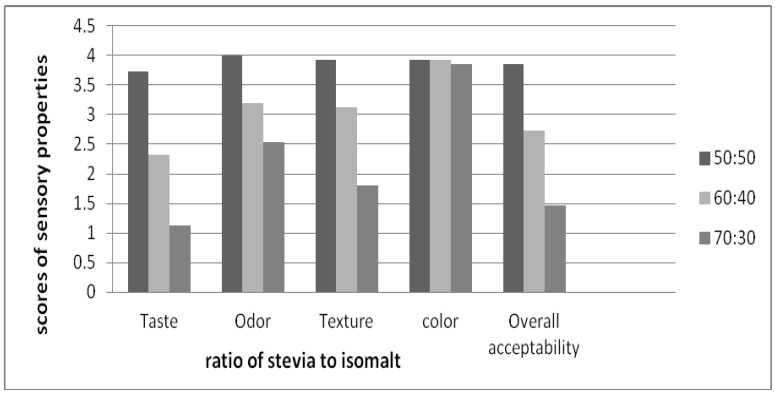

Fig. 1: Effect of stevia and isomalt substituting on sensory properties of ice cream samples.

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