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Investigating the Effects of Inulin as a Carbohydrate Based Fat Replacer on Rheological and Sensory Properties of UHT Cream

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Abstract

The problems associated with the consumption of high-fat foods have increased the requirement to use new formulations based on fat replacer. Inulin has textural properties and it's a prebiotic source. Due to the cream's wide usage in dairy industry, it is tried to make cream with textural and organoleptic characteristics that contains the least amount of calories. Meanwhile, Table cream (30%) was used as basis for production and the treatments were added to the different containers which contain skim milk and the temperature was raised to about 70 °C to completely dissolve the mixture. Then, skim milk containing hydrocolloids (T_1 = 0, T_2 = 0.5%, T_3 = 1%, T_4 = 1/5%, T_5 = 2 and T_6 = 2/5% w/w) were added to the cream tanks until the fat percentage was reached to 10%. After performing of the "two-stage homogenization" process which carried out at 150 bar under temperature of 70 °C, the pasteurization process was executed. The control sample was prepared with a fat content of 30%. After packing, samples stability was investigated every 10 days during the 2 months by rheological, physicochemical and sensory tests. In this study in order to analysis of the results, ANOVA and Duncan's multiple range test ($P \leq 5\%$) were used and all tests were done in three replications. According to the results of this study, in terms of physicochemical and rheological properties, T_6 and T_5 treatments and regarding to sensory characteristics T_1, T_2 and T_3 treatments found as superior formulations in maintenance periods.

Keywords: Sterilized cream (UHT cream), Inulin, Physicochemical and Rheological properties, Sensory evaluation

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1. Introduction

Evidence and scientific findings have shown that there is a close relationship between high consumption of fat and diseases such as obesity, hardening of the walls of the veins, increased blood pressure and cardiovascular disease. Following this issue and increasing the public's awareness about the consumption of fat and its detriment, there has been a significant increase in the demand for low-fat foods. Dairy products are one of the most widely used fats alternative products (Kavas et al., 2004). From the nutritional point of view, proteins, fats and carbohydrates are the main sources of energy, and the role of lipids and carbohydrates is more important than proteins. In addition to the nutritional aspects of fats, they also affect the sensory properties of foods, including taste and mouthfeel and texture. Therefore, to formulate low-fat products, the use of ingredients that are relatively or completely substituted It is recommended.

Fat substitutes affect the product's characteristics such as taste, mouthfeel, texture, viscosity and other organoleptic properties. Substances are used as a fat substitute in the dairy industry are two categories: imitation fats and fat substitutes (Tamim, 2005). Fat mimetics are substances that imitate organoleptic or physical properties of triglycerides but which cannot replace fat on a one-to-one, gram-for-gram basis. Fat mimetics, often called protein- or carbohydrate-based fat replacers. Among them, carbohydrate-based alternatives are more used in the preparation of low-fat foods such as ice cream, yogurt and frozen desserts (Drake et al., 1999). Inulin is non-digestible fructans of interest in human nutrition due to its prebiotic effect, i.e. specific stimulation of growth and/or activity of colonic bacteria that benefit the host, as well as inhibiting the growth of pathogens and harmful microorganisms (Carabin and Flamm, 1999; Tamime, 2005; Roberfroid, 2007). Carbohydrate-based fat substitutes, such as inulin, starches and gums, have many unique properties. They hold water, impart a creamy texture, add form and structure that are similar to fat. However, they cannot be used for cooking or frying (Roberfroid et al., 2005; Verbeke et al., 2005). Inulin as fat substitutes is used in the production of low-fat cheeses and low-fat yogurt (Akalin et al., 2008).

1.1. Cream

Cream is a dairy product composed of the higher-butterfat layer skimmed from the top of milk before homogenization. Cream flavor is one of the most important features of it, and especially lipolysis and oxidation have a very adverse effect on its quality. Cream types are classified in terms of fat percentage, which varies between 10% to 50%. In Iran, Table cream with at least 30% fat is produced.

1.2. UHT cream

Creams are categorized into two types including Pasteurized and UHT. Pasteurized Cream is a cream that has been pasteurized by one of the known thermal treatments in dairy industry. UHT cream is a cream that is packaged in a sterilized or sterile condition through the UHT process (Amiri and Ahmadi, 2014). The Effect of long-chain inulin on the rheological properties Containing Different Fatty Amounts was investigated and compared with two types of commercial fat replacer. The results showed that the viscosity of samples containing 4% and 6% inulin are similar to control Sample. However, the sample containing 8% inulin exhibited higher viscosity values (Roberfroid et al., 2005; Verbeke et al., 2005).

In other study, by response surface methodology (RSM) with central composite design, the influence of inulin (0-4 % w/w) and polydextrose (0-4 w/w) in low-fat cream were investigated on qualitative properties. The results showed that increasing the inulin and polydextrose contents caused a significant ($P \leq 0.05$) decrease in the phase separation. Regarding the rheological parameters, it was observed that inulin and polydextrose caused a significant ($P \leq 0.05$) increase in the storage modulus, loss modulus and viscosity. Evaluation of the organoleptic properties showed that addition of inulin and polydextrose caused a double impact on the sensory properties, and sensory parameters improved up to medium concentrations of inulin and polydextrose (Orouji et al., 2017).

The use of inulin is not restricted to its properties as a fat replacer and because recent research has indicated its prebiotic properties, inulin is now considered to be a functional ingredient (Sahan et al., 2008). The present research was thus aimed to investigate the possibility of substituting the table cream fat with inulin to manufacture a low-fat table cream with prebiotic properties through scrutinizing the effect of this substitution on the physicochemical, rheological and sensory properties of the table cream.

2. Materials and methods

The materials used to produce low-fat cream in the current study were milk (2.5% fat and 9.3% non-fat dry matter) and cream (30% fat and 35% dry matter) from Milk Company Pegah Fars. Also, inulin was purchased with a purity of 96% from Sensus Netherlands. The study population consisted of six treatments including control sample. The random sampling method was used and the tests were designed and performed in three replications (Table 1). Each of the cream samples has different fat percentages (30-5%), which are produced by using different inulin percentages and by using stabilizer (0.05%).

Table 1
Examples examined.

Samples	Fat (%)	Inulin (%)
T1 (control)	30	0
T2	25	0.5
T3	20	1
T4	15	1.5
T5	10	2
T6	5	2.5

Initial cream was received with acidity 14 °D and 30% fat content standardized by the Separator. Then, the treatments were added to the skim milk (0.05%) in different tanks and the temperature was increased to about 70°C until the mixture was completely combined. After that, the treatments containing hydrocolloids (T_1 = 0, T_2 = 5%, T_3 = 1%, T_4 = 1/5%, T_5 = 2 and T_6 = 2.5% w/w) were added to the cream tanks to achieve a 5% fat percentage. The control sample was prepared with a fat content of 30%. After performing of the "two-stage homogenization" process which carried out at 150 bar under temperature of 70 °C, the pasteurization process was executed. Afterward packing, samples stability was investigated every 10 days during the 2 months by rheological, physicochemical and sensory tests. Fig. 1 shows the process of production of porridges and pasteurized cream in the industry.

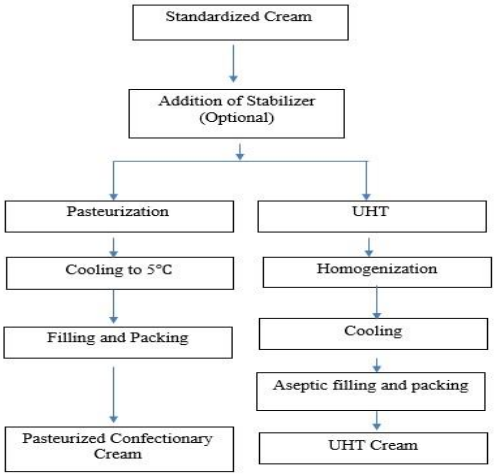

Fig. 1. Flowchart of pasteurized cream and UHT cream production in industry (National Iranian Standard No. 191).

2.1. Physicochemical tests

Chemical properties were measured by using guidelines (AOAC, 2000). The pH was measured using a digital pH meter (Model 827, Metrohm made in Switzerland). To determine the acidity, titration with Sodium hydroxide (0/1 N) was carried out, and the acidity was reported in Lactic acid (Iranian National Standard No. 2852). The fat was determined by Gerber method.

2.2. Moisture content

To calculate the moisture content of the food, an oven, a glass plate, a digital scale with a precision of 0.001, a desiccator and a clamp was required. The method of doing the test is to first turn on the oven and adjust its degree to 105 degrees.

$$\text{Moisture content} = \frac{M_1 - M_2}{M1} \times 100$$

M_1: Weight of container and sample before drying, M_2: Weight of container and sample after drying

2.3. Dry matter

The total amount of food, regardless of moisture content, is called dry matter, which includes total protein, fat, crude fiber and mineral elements in the food. To determine the percentage of dry matter, the percentage of moisture content was deducted from 100 and the amount of dry matter was obtained.

$$\text{Dry matter percentage} = 100 - \text{Moisture content}$$

2.4. Rheological test (Synersis)

To determine the Synersis, 10 g of different samples were placed in a graduated laboratory tube and centrifuged at a speed of 1058 rpm for 5 minutes at 30 °C. Then, the volume of aqueous phase isolated from the cream was recorded in milliliters (Rafiee Tari et al., 2006). Viscosity measurements of the samples were performed by using a Brookfield RV (Viscosity Meter) at a range of 2.5 to 50 rpm at 30 s at 4 °C by the UL Adapter spindle and using duct s / s304 with 15 ml Sample was calculated in each experiment.

2.5. Sensory evaluation

In order to perform sensory tests, 7 trained panelists were selected. Using five-point hedonic scale, the samples were evaluated for color characteristics, appearance, consistency, taste, mouthfeel and overall acceptance. Samples were prepared in a volume of about 25 ml in a white container. Then, each panelist served the samples in three replicates with score sheet and scored from 1 to 5 to each samples. So the sample has the highest score received 5 and the sample with the lowest score took 1 (Gomez et al., 2007).

2.6. Statistical analysis

The experiments were repeated in three time randomly and analyzed with SAS software. ANOVA was applied to compare the averages and Duncan's multiple range test was applied $P \leq 5\%$.

3. Results and discussion

3.1. Acidity and pH changes

The trend of pH changes in samples with decreasing fat content from 30 to 5% and increasing inulin from 0 to 2/5 was in the range of 6.6-5.75 and the acidity range is 0.09-0.15% in terms of lactic acid. The highest pH was observed on the first day of production in T_1 and T_2, in addition the lowest pH was reported on the same day in T_6 and T_5, respectively. However, there was no significant difference in pH between 30 and 60 days in T_2, T_3 and T_4 samples during storage time, respectively. The pH reduction is probably due to the breakdown of some of the ester groups and their conversion into acid groups. On the other hand, the growth of acid-resistant non-pathogenic bacteria, such as lactobacilli, may also be effective. Likewise, the results indicated that with decreasing pH, acidity increased in all treatments. This increase was more marked in T_6 treatment compared to other samples.

3.2. Fat alterations

The results of the statistical analysis and analysis showed that by decreasing the fat content from 30 to 5% and increasing the amount of inulin from 0 to 2.5%, the fat percentage significantly decreased. The highest percentage of fat during the storage was observed in T_1 and T_2 treatments, respectively, and the lowest amount was reported on T_6 and T_5 treatments, in turn.

3.3. Dry matter changes (Total solids content)

Changes in solids content during the storage were evaluated and the results indicated that by reducing fat content from 30 to 5% and raising of inulin content from 0 to 2.5% caused the total amount of solids to be significantly reduced in all treatments. The highest amount of solids content in all maintenance periods was reported in T_1 and T_2 treatments, and the lowest in T_6 and T_5 treatments, respectively.

3.4. Moisture content changes

The trend of changes in moisture content in different treatments during storage with decreasing fat content from 30 to 5% and increasing in inulin from 0 to 2.5% has increased meaningfully. In general, the lowest and highest moisture content in all storage time was dedicated to T_1 and T_6 respectively.

As the results showed, moisture content was increased by decreasing the amount of fat in the treatments, which is probably due to the structure of fat molecules and its hydrophobicity properties. Increasing of inulin content improved water absorption in comparison with the control sample but changes in water holding have not been significant over time. It should be noted that the table cream with denser structure has a higher water holding capacity (Zhao et al., 2008).

3.5. Rheological tests (Synersis)

One of the most important issues in cream production is synersis after manufacturing, which reduces acceptance and consumption (Gholamhosseinpour and Mazaheri Tehrani, 2011). By reducing fat in the cream formulation, synersis increased, which is related to the reduction of the mechanical strength of the protein network. Dry matter-enrichment as well as the addition of hydrocolloids are commonly used methods to prevent synersis (Sahan et al., 2008). Inulin has a good potential as a stabilizer in cream formulation. The effect of adding inulin on the superficial properties of fatty acids and in the stability of the cream plays an important role and avoids or reduces synersis. The addition of inulin reduced the amount of cream synersis during storage and also increased the UHT cream's stability. This is due to the reaction of inulin with casein micelles, which leads to the formation of binds between the lipid membranes and the water phase in the cream and increases the integrity and stability of the emulsion. Also, different amounts of inulin, indicated the direct relationship of UHT cream stability with the extent of inulin. In fact, with the further breakdown of cream fatty acids and the growth in the level of fats, more equilibrium is needed to reduce the surface tension between the fat phase and the water phase. The use of inulin has reduced the hardness and increased adhesion of the samples to the control sample. Addition of the inulin has a significant effect only on high concentrations, in other words, at least synersis occurs at the maximum amount of inulin. Prebiotic fiber, including inulin, is a polysaccharide compound that acts as a water absorbent and prevents water leakage by blocking water and creating a gel network (Gustaw et al., 2011). According to the results obtained from this study (Fig. 2), on the first, 30th and 60th days, T_6 and T_5 treatments had the lowest synersis in all samples, respectively, and the highest amount synersis was reported for T_1 and T_2 treatments in turn. In fact, by decreasing the fat percentage from 30 to 5% and increasing the amount of inulin from 0 to 2.5%, the rate of synersis in all samples decreased significantly. However, there was no significant difference between the T_1, T_2 and T_3 samples.

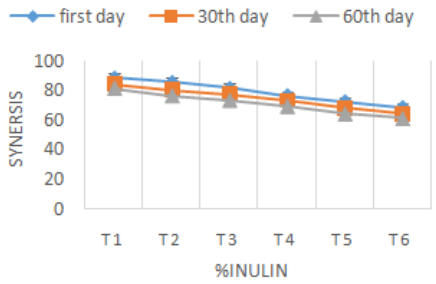

Fig. 2. Changes in synersis through increased inulin concentration during storage.

3.6. Apparent viscosity

In this study, results showed that usage of inulin leaded to reduce the hardness and increased adhesion of the samples compared to the control sample, and samples containing inulin indicated higher viscosity. In general,

the highest mean viscosity during maintenance periods was related to T_6 and T_5 treatments and the lowest on day 60th, belonged to T_1 treatment. There was a significant difference between treatments during the storage in terms of viscosity. In fact, with the increase storage time, viscosity of the entire sample was increased, which is due to protein rearrangement and Changing in protein-protein binding. Increasing hydration can be another reason for increasing viscosity over time.

Emulsions are stabilized by placing proteins around oil droplets that prevent particles from mixing. Polysaccharides, such as gums are stabilizer and act by increasing the viscosity of the continuous phase and decreasing the movement of oil droplets and viscoelastic films formed around the oil and thus stabilize the oil emulsion in the water. As previously noted, the addition of hydrocolloids increases the absorption capacity of water, which results in two important physical effects, one reduction of water content and another increase in apparent viscosity (Aminigo et al., 2009; Kip et al., 2006).

According to the results of this research (Fig. 3), in all maintenance periods, the highest viscosity was observed in T_6 and T_5 samples, respectively, and the lowest viscosity was reported in the T_1 and T_2 samples respectively. By decreasing fat percentage from 30 to 5% and increasing inulin from 0 to 2.5%, viscosity increased significantly in different treatments, although, on the 30th day, no significant differences were observed between T_2 and T_3 and T_4 treatments.

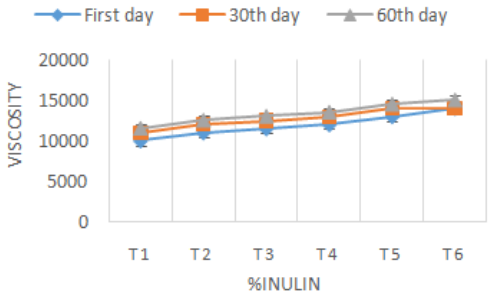

Fig. 3. Viscosity variations over increasing inulin concentration during storage.

3.7. Investigating the effect of independent variable on color, consistency, taste, appearance, mouthfeel and overall acceptance

Analysis of variance of inulin on color showed that the effect of treatments on color during the storage was significant at ($p<0.05$). The highest scores were given to the T_1 and T_2, and the lowest points were given to the T_6 sample. According to the panelists, reducing the fat percentage and increasing the amount of inulin have reduced the color quality of the cream samples. There was a significant difference between the results of the consistency for the treatments in the first, 30th and 60th days after the production. In all storage periods, the highest scores were attributed to samples T_1, T_3 and T_4 respectively, and the lowest point was given to T_6 and T_5 in turn. By reducing the percentage of fat in the samples, the consistency of the produced cream has decreased and 30, 20 and 15% fat treatments respectively have the highest consistency.

In terms of appearance, the T_6 sample obtained the lowest scores and the T_1 and T_2 treatments received the highest points respectively, and in the different periods of time the trend was similarly observed. Regarding to flavor characteristics in the first, 30th and 60th days after production, the highest score was given to the T_1 and T_3 samples and the lowest score was given to T_5 and T_6 respectively.

In terms of mouthfeel in the first, 30th and 60th days, the treatments had a significant difference. On the first and the 30th days, the highest scores were given to the T_1 and T_3 treatments respectively and the T_5 and T_6 received the lowest scores in turn. But on the 60th day, the highest score was obtained for T_1 and T_2 samples and the lowest score was given to T_5 and T_6 samples respectively. According to the panelists, reducing the percentage of fat and increasing the percentage of inulin has reduced this feature. In terms of overall acceptance, in the first, 30th and 60th days, the panelists gave the highest scores to T1, T2 and T3 samples respectively and the sample T6 and T5 was given the lowest scores respectively.

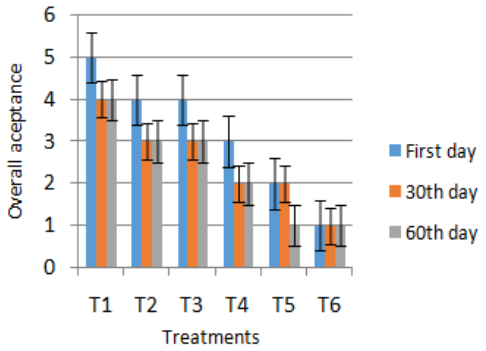

Fig. 4. Evaluation of overall acceptance of treatments during storage.

4. Conclusion

By adding inulin to a low-fat cream, you can find a product that is, in terms of texture and other characteristics, very close to high-fat cream. Inulin as a dietary fiber and having the properties of prebiotics in cream production to enhance the nutritional and technological properties and prevent the effects of fat abuse on the health is very important. In terms of physical, chemical and rheological properties, T_6 and T_5 treatments are selected as superior formulations of this study in maintenance periods, and are more acceptable. However, In terms of sensory characteristics, T_1, T_2 and T_3 treatments have been selected as superior formulations of this research in maintenance periods and are more acceptable.

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