CHANGES OF AGAR-AGAR GEL PROPERTIES AFTER REPLACING SUCROSE BY INULIN SYRUP

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Abstract

A lot of research has been carried out to substitute the sugar in food products by other sweeteners since sugar consumption is directly related to diabetes and other illnesses such as obesity. Inulin is more commonly known as a prebiotic, soluble dietary fiber. In literature there is comparatively little information about inulin as a sweetener. Inulin syrup used in the research was obtained from the Jerusalem artichoke (*Helianthus tuberosus* L.) tubers. Therefore the aim of the research work was to evaluate properties of agar-agar gel when sucrose was replaced by inulin syrup. Agar-agar gel samples were prepared with different concentrations of inulin syrup to replace sucrose: 0%, 20%, 40%, 60%, 80% and 100%. Gel samples were prepared by adding inulin syrup at specific temperatures: 65 °C and 105 °C. To analyse the texture of the gel samples the Texture Analyser Model TA.XT Plus was used by slicing samples with a wire cutter (A/BC) while the colour was determined in the system of CIE L* a* b* by using the Colour Tec-PCM, and for pH measurements – a pH-metre Jenway 3510 with a combined glass electrode was used.

The results of texture analysis show that strength (hardness) of the gel is influenced by the temperature as well as the concentration of the inulin syrup added to the gel samples. In the structure analysis the strength of the gel samples ranges from 7.406±0.656 N to 10.001±0.730 N and the strength increases in samples when a higher concentration of inulin syrup is added at a temperature of 65 ˚C, but an opposite situation is observed in the gel samples when prepared at a temperature of 105 ˚C. The colour parameter L*, which describes lightness of the sample, ranges from 20.92 (20% of inulin) to 18.11 (100% of inulin) while pH of the gel samples ranges from 3.29 (20% of inulin) to 4.18 (100% of inulin).

Key words: inulin syrup, agar-agar, gels.

Introduction

A valuable and balanced diet, safe and qualitative foodstuffs are the basic principles of people's health and life quality improvement. The main criteria of qualitative food are its wholeness, variety and moderation.

The problem of cardiovascular diseases and the related nutritional problems like obesity and overweight have become an important issue in Latvia lately. One of the causes of this problem is a high consumption of sweets between the main meals.

The sensory feeling of sweetness is one of the five primary taste qualities, and there are several measures of human perception of sweetness.

Traditionally, sucrose has been the sweetener of choice, though a wide range of sugars have been available for bakers. These sugars are derived from the hydrolysis of cereal starch, such as glucose and fructose syrups. Apart from its sweetening action, sugar performs a variety of functions: formation of crust colour, flavour enhancer, texture modifier, development of structure, and shelf-life improvement.

Over the last two decades, inulin-type fructans have become a topic of interest for both food industry and for researchers (Roberfroid, 2005, Gedrovica et al., 2009). Since sugar consumption is directly related to diabetes and other illnesses such as obesity, there is an increased interest in products without added sugar. Jellies are not basic foods, but they are good complements to a diet if they are eaten in correct amounts (Figuerola et al., 2007). Jellies are high-energy products, meaning that the products are not suitable or desirable for people who have glycemic problems, obesity, diabetes, and cardiovascular diseases. Low sugar, on the other hand, means difficulties in gel formation and problems with product texture, stability, and uniformity.

Replacing sugar in jellies, technological problems arise because of the fact that in order to obtain the desired sweet taste in jellies, sugar is essential to form the product structure using the gels with pectin or other gelling material. Some hydrocolloids can be used in low-sugar

jelly formulations by obtaining different product quality. When the amount of sugar in jelly production is decreased or even eliminated, agar is one of the gelling substances that could be used to compensate for sugar and its properties.
Agar is a hydrophilic colloid extracted from certain marine algae of the class *Rhodophyceae*. Agar has been used for many centuries as a high performance gelling agent (Armisen et al., 2000; Stanley, 2006). Its ability to produce clear, colourless, odourless, and natural gels without the support of other colloids has long been exploited by the food industry not only as a stabilizer and gelling agent but also in the manufacturing of confectionery. Agar jellifies at 40 °C and melts at 80 °C (Barrangou et al., 2006).
Agar is a well known thermo-reversible gelling polysaccharide, which sets at 30 to 40 °C. Inulin is legally classified as food or a food ingredient, and not as additive in all countries where it is used (Roberfroid, 2005). In addition to pure inulin and fructooligosaccharides, the Jerusalem artichoke is processed in a number of different ways for the health food market (Frack, 2002; Kaur et al., 2002). The Jerusalem artichoke flour is used in a wide range of foods, such as pasta for diabetic diets, while extracts are sold in pill form for their health-promoting properties. In the food industry, it is used as a prebiotic ingredient and a low-calorie sweetener (Glibowski et al., 2008). Therefore the aim of the research work was to evaluate the properties of agar-agar gel prepared at two different temperatures (65 °C and 105 °C) when sucrose was replaced by inulin syrup.

Materials and Methods

The research was carried out at the Latvia University of Agriculture, Faculty of Food Technology.
In gel production the Jerusalem Artichoke Juice Concentrate produced by Topina, Diät Rohstoff Gmb, (Germany) inulin syrup was used to replace sugar, while glucose syrup was obtained from the confectionary factory "Laima" (Latvia).
Sugar and citric acid were purchased in a local grocery store. In the preparation of gelling substance AgarNordS (E 406) (Estonia) was used. It is a low calorie material (non-digestible by humans).
Ten different gel samples were prepared using various concentrations of inulin syrup with agar-agar, sucrose, glucose syrup. To prepare the control sample the following recipe was used: agar-agar powder (2 g), glucose syrup (62 g) – sucrose (104 g), citric acid (2 g of 50% citric acid solution) water (100 g) (Дубцов, 2001; Сборник основных рецептур, 2000). In the research the replacement of sucrose by inulin syrup was in the following range of ratios: 100/0, 80/20; 60/40; 40/60; 20/80; 0/100 %.
Agar-agar was swollen in cold water, and then the mixture was heated until agar-agar was dissolved in water.
1st option: agar-agar/water solution was boiled for 5 minutes at a temperature of 105 °C. Afterwards, the sucrose or inulin syrup, citric acid and the glucose syrup were added to the boiled solution and cooled down to 65 °C.
2nd option: agar-agar/water solution was boiled for 5 minutes at a temperature of 105 °C then cooled down to 65 °C. Then sucrose or inulin syrup, citric acid and the glucose syrup were added to the boiled solution and cooled agar-agar solution.
Subsequently, the obtained agar-agar/water with sugars and citric acid solution was hot–filled in polystyrene containers (150 ml), which were sealed with their covers and cooled down to 18 °C.
The analyses of the colour, structure and pH were carried out on the next day after all kinds of gel samples were prepared.

The measurement of pH was determined by – the pH-metre (Jenway 3510) with a combined glass electrode. During the pH analysis, the glass electrode was immersed in the jelly samples. The measurements of pH were repeated three times.
The strength (hardness) of gel was characterised by texture profile analysis. The texture was determined using the Texture Analyser Model TA.XT Plus; Stable Micro Systems. The wire cutter (A/BC) was used to slice the gel samples. The measurement was repeated ten times obtaining precise results of the structure analysis.
The colour of the gels was determined in the system of CIE L* a* b* by using Colour Tec-PCM measure and the obtained values were expressed as L* a* b* values.
The data were processed by using *Microsoft Excel* programme.

Results and Discussion
For developing new products that meet the people's needs for a non-sugar diet, most of the foods are prepared by substituting sugar with sugar replacers – other sweeteners which give lower calories (sugar gives 4 kcal while fibre -2 kcal per g of the product) (Commission Directive 90/496/EU, Commission Directive 2008/100/EU). Jelly is a product manufactured by cooking fruit juice with added sugar, glucose syrup and agar-agar (Figuerola, 2007). Sugar serves as a preserving agent and aids in gelling. Too little sugar prevents gelling and may allow yeast and moulds to grow. For proper structure, jelly products require the correct combination of agar, sugar and glucose syrup (Tabata, 1999; Bayarri, 2004). In order to examine how the strength (hardness) of gel changes, the development of an optimum gel model is in progress without adding any extra taste, smell and colour additives (e.g fruit or berry juice).
In our research the inulin syrup is used as a sugar replacer therefore we are investigating the quality differences between the standard recipe of gel and experimental products where sugar is replaced by inulin syrup. Since oligosaccharides give a lower calorie content (around 2 kcal per g) it is suggested that sugar be replaced by inulin as an oligosaccharide which is important for those consumers who like to consume jelly candies (where sugar is used) and have weight problems.
The pH of gels ensured the storage stability and inhibition of the growth of moulds and yeasts. In terms of agar-agar gels, gelling properties change when pH changes.
The pH of experimental gels was not changed in a wide range. The pH value of the control samples was 2.42. Low pH level of the gel solutions can be explained by adding citric acid (described in the section 'Materials and Methods'). The pH values of other samples analysed in the research ranged from 3.11 (20%) to 4.01 (100% of inulin syrup) when samples were prepared at 65 °C, while in the samples prepared at 105 °C the pH values ranged from 3.29 (20%) to 4.18 (100 %) (Figure 1).

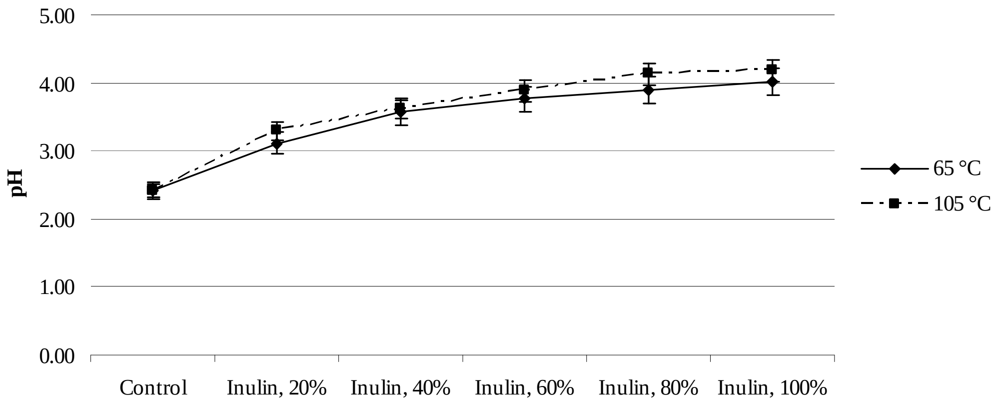

Figure 1 Changes of pH in gel samples

By adding inulin syrup (pH 4.7) in the production of gel solutions, the pH value increased compared to the control samples (without inulin syrup).

Regarding the gel strength (hardness), the data of gel structure in the literature sources are insufficient. Even very minor changes in composition or processing variables can dramatically influence the textural properties of jellies (Kim et al., 2001, Matsuhashi, 1990, Panouille et al., 2009).

The strength of experimental gels was affected significantly by chosen inulin syrup concentration and heating temperature. The changes are shown in Figure 2.

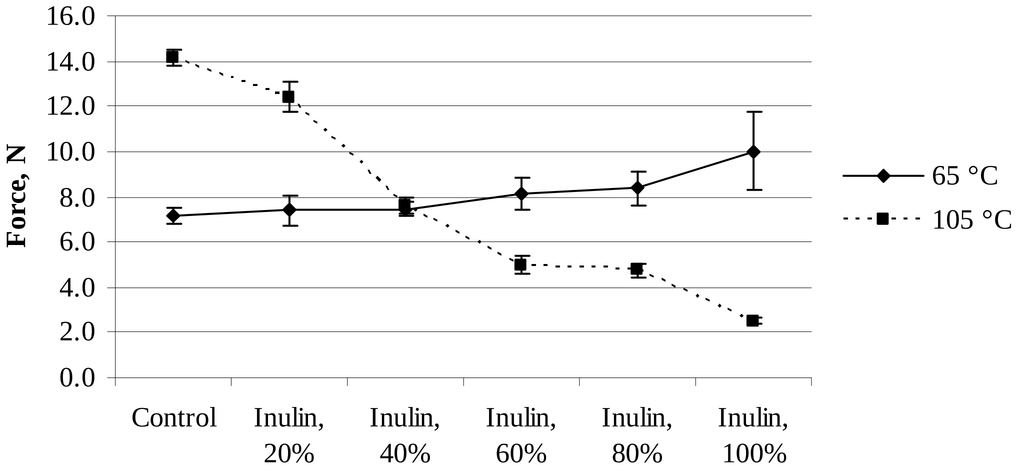

Figure 2 Changes of strength in gel samples

The strength increased by increasing the concentration of inulin syrup which was added at a temperature of 65 °C and it ranged from 7.406±0.656 to 10.001±1.730 N. In the gel sample production, inulin concentration influences both the taste and strength of the gels.

An opposite situation was observed at a temperature of 105 ºC. The strength of gels decreased from 12.419±0.679 to 2.490±0.126N. The decrease in hardness of the gels can be explained by the properties of inulin at a certain temperature. In this case, gel production at a temperature lower than 70 ºC affects its gelling ability, while adding inulin at 105 ºC water binding capacity increases forming a colloidal grid.

We could put forward a hypothesis that such a situation has been caused by the properties of agar-agar and inulin and their different gelling temperatures. If we add inulin syrup to the gel solution at 105 °C, the concentrations of inulin influence the gel strength. While adding inulin syrup to the gel solution at 65 ºC the gel is already formed by the agar-agar and the concentration of inulin syrup has a very small influence on the strength of the gel.

Agar and inulin as polysaccharides have the ability to form a gel and its strength depends on the properties and concentration of polysaccharides. By replacing sucrose with inulin the strength of the gel increases. The strength of the gels become weaker when inulin syrup is added at a temperature of 65 ºC, and the strength of the gels slightly increases by increasing the concentration of inulin. Adding inulin syrup to the gels at a temperature of 105 ºC, the strength of the gel decreases sharply.

From the obtained results it can be concluded that during gel formation agar-agar needs to have a sufficient amount of free – unbound water available to form a gel with proper strength and structure.

In food perception certain factors play a very important role – eg. structure, smell and colour.

When a food product is evaluated for consumption all the senses play an important part. A food product is accepted or rejected. The colour is one of the main characteristics of food quality. Most consumers associate gel with a bright and mainly light colour. The results of surface colour measurements of experimental gels are presented in Fig ure 3 and Figure 4.

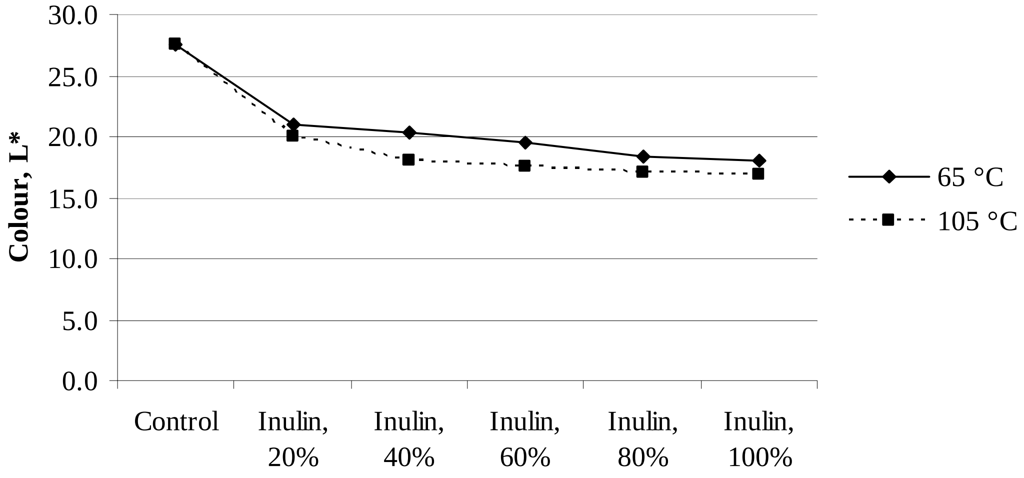

Figure 3 Changes of the lightness "L*" of gel samples

By increasing the inulin syrup ratio in experimental gels the mixture obtains a darker colour than the standard mixture in both cases, since inulin syrup is darker in colour. From the Fig 3 it can be seen that the lightness L* of gels decreases in all samples prepared at a temperature of 65 ºC as well as at 105 °C from 20.92 (20% of inulin syrup) to 18.11 (100% of inulin syrup) and from 20.02 (20%) to 16.98(100%). The gel samples are in a dark colour, and that can influence the consumers' choice in purchasing these products.
Experimental gels' yellowness b* increases from 4.85 to 6.38 (temperature 65 °C), and from 4.99 till 6.97 (temperature 100 ºC) (Fig. 4).

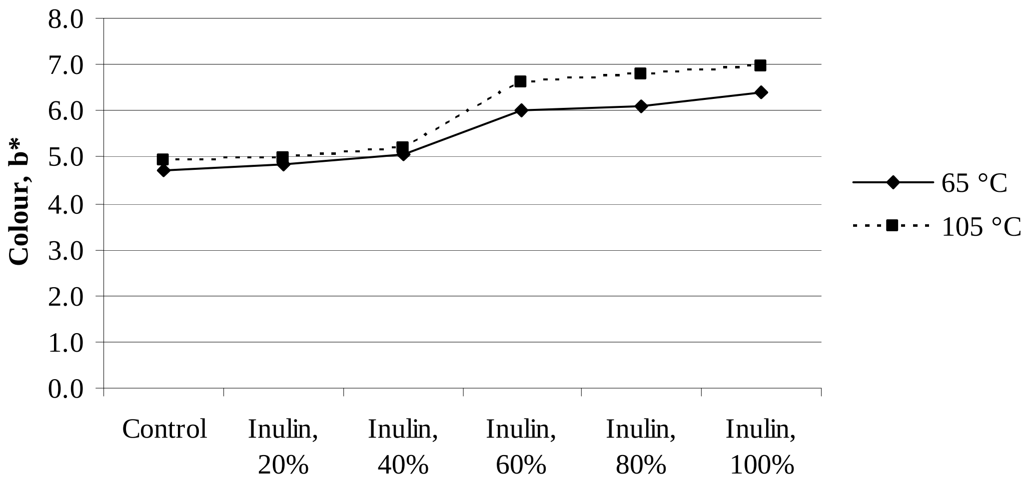

Figure 4. Yellowness b* in gel samples

The values of colour factor a* have been determined, but they have not been described in the research because they do not characterise the colour of the gel samples.

Conclusions

1. Inulin syrup can be used as sugar replacer in manufacturing of new gel products.

2. Gel strength increased by adding inulin syrup to the standard solution at a temperature of 65 ºC from 7 N to 10 N, but by adding inulin syrup to standard solution at a temperature of 105 ºC, the strength decreases.
3. When gel samples were prepared at 65 ºC, pH ranged from 3.11 to 4.01 while at a temperature of 105 ºC – from 3.29 to 4.18.
4. The added amount of inulin syrup influenced the lightness of gel samples.

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