# DEVELOPMENT OF LACTOSE FREE DAIRY DESSERT

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**I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.**

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# ABSTRACT

## DEVELOPMENT OF LACTOSE FREE DAIRY DESSERT

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A recent trend in food industry is to develop lactose free food products due to the large number of consumers suffering from lactose intolerance. In this study, lactose free desserts were developed by using two different starches; waxy maize and amylomaize. Concentrations of waxy maize and amylomaize were 0.032, 0.040, 0.048 g/ml and 0.064, 0.072, 0.080 g/ml, respectively. Lower concentration of waxy maize starch was enough for body formation and gel like structure, implying waxy maize was more effective in dessert production.

Also the effects of gum type and concentration on the physical properties of lactose free desserts were investigated. Guar, arabic and κ-carrageenan gums were used at two different concentrations (1% and 0.5%) in the formulations. Among them κ-carrageenan was the most effective one, leading by guar and arabic gum. Increasing gum concentrations led to improvement in the textural properties of dairy desserts. Effect of sucrose concentrations (0.10 g/ml and 0.14 g/ml) on waxy maize and amylomaize was different. Addition of sucrose caused decrease in textural properties of waxy maize starch containing desserts, on the other hand sucrose addition increased textural properties of amylomaize containing desserts. In addition, lactose free dessert formulation containing the same concentration of sucrose with lactose containing desserts was less liked by the panelists. Therefore, it is required to reduce the amount of sucrose in lactose free dessert production. Lactose free dessert with reduced sucrose was the most acceptable formulation in terms of texture also. Color of different dessert formulations was similar.

NMR spin-spin relaxation times were obtained for desserts with different formulations in order to better understand molecular level of gelatinization and results showed that starch and gums compete for water in the medium.

Comparison of lactose containing and lactose free desserts was carried out too. Results show that texture of desserts were similar when waxy maize starch was used with 0.14 g/ml sucrose concentration. However, when amylomaize was used lactose containing desserts had lower textural properties than those of lactose free desserts.

Keywords: Amylomaize; dessert; lactose free; lactose intolerance; milk; sucrose; waxy maize

# ÖZ

## LAKTOZSUZ SÜT TATLISININ GELİŞTİRİLMESİ

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Laktoz tahammülsüzlüğü olan tüketicilerin oldukça fazla sayıda olması nedeniyle gıda endüstrisinde laktoz içermeyen ürünlerin geliştirilmesine yönelik bir eğilim vardır. Bu çalışmada iki farklı mısır nişasta çeşidi, mumsu mısır ve amilozu yüksek mısır, kullanılarak laktozsuz süt tatlısı tasarlanmıştır. Mumsu mısır ve amilozu yüksek mısır nişastaları için kullanılan konsantrasyonlar sırasıyla, 0.032, 0.040, 0.048 g/ml ve 0.064, 0.072, 0.080 g/ml dir. Tatlının jel yapısının oluşması için daha az mumsu mısır nişastası kullanmak yeterli olmuştur bu da mumsu mısır nişastasının süt tatlısı üretiminde daha etkili olduğunu gösteriyor.

Tatlılar üzerinde zamk çeşidi ve konsantrasyonunun etkisi de analiz edilmiştir. Tatlı formülasyonlarında üç farklı zamk çeşidi (guar, arap ve κ-carrageenan) iki farklı konsantrasyonda (% 0.5 ve % 1) kullanılmıştır. Zamklar arasında en etkilisi κ-carrageenan, daha sonra ise guar ve arap zamkı olmuştur. Zamk konsantrasyonunun artırılması, tatlıların tekstürel özelliklerinin artmasına sebebiyet vermiştir. Sükroz konsantrasyonunun etkisi nişasta çeşidine göre farklılık gösterdi. Sükroz konsantrasyonunun artırılması mumsu mısır nişastası kullanılan nişastalarda tekstürel özellikleri düşürürken, amilozu yüksek nişasta kullanılan tatlılarda tekstürel özelliklerin arttırmıştır. Ayrıca, laktoz içeren tatlılarda kullanılan sükroz konsantrasyonuna sahip laktozsuz süt tatlıları panelistler tarafından en az sevilen tatlı formulasyonu olmuştur. Bu nedenle laktozsuz süt tatlılarının üretiminde sükroz

miktarını azaltmak gereklidir. Düşük şekerli laktozsuz tatlılar tekstür açısından da en kabul edilebilir formulasyon olmuştur. Farklı tatlı formulasyonlarının renkleri benzer bulunmuştur. NMR sonuçları nişasta ve zamkın su için birbirleriyle yarıştığını göstermektedir.

Aynı zamanda laktoz içeren ve laktozsuz süt tatlıları da karşılaştırılmıştır. Laktoz içeren tatlılarla laktozsuz tatlılar, mumsu mısır ve aynı oranda sükroz konsantrasyonu (0.14 g/ml) kullanıldığında yakın tekstürel özellikler göstermişlerdir. Amilozu yüksek mısır nişastası kullanıldığındaysa laktoz içeren tatlıların tekstüre özellikleri laktozsuza kıyasla daha düşük olmuştur.

Anahtar Kelimeler: Amilozu yüksek mısır nişastası; tatlı; laktozsuz, laktoz tahammülsüzlüğü; süt; mumsu mısır nişastası

***To my beloved family…***

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# INTRODUCTION

## 1.1 Milk

Milk is a food that is secreted from mammary glands of mammals for the aim of feeding young offspring. Milk as a food serves some objectives such as growth, muscle build up, maintenance and repair, reproduction (Pieter et al., 2006).

Cow is the main source of milk that human consume but goat, buffalo and sheep milk are also consumed either as or in the form of dairy products. Milk is mostly composed of water (Pieter et al., 2006). According to the type of the milk, amount of protein, carbohydrate and lipid vary (Pieter et al., 2006). From nutritive point of view, milk is rich in terms of vitamins, minerals and other fat-soluble and water-soluble components derived directly from specific blood proteins (Alan and Jane, 1996). Milk is an extreme source of vital vitamins such as riboflavin, vitamin A, D, $B_1$ and $B_6$ and also calcium and phosphorus which are good for bones and teeth. Beside milk’s nutritional values, biologically active compounds such as casein and whey protein have been concluded to be very important for biochemical and physiological functions that have crucial roles on human metabolism and health. The calcium amount that milk contains in high amounts is very important for its enrollment in development, strength and density of bones, retardation of osteoporosis, controlling body weight and blood pressure and also reducing cholesterol absorption (Young, 2009).

Latest studies have proven that biologically active compounds that are found in milk such as immunoglobulins, antibacterial peptides, antimicrobial proteins and multitudinous other components at low concentrations protect against illnesses and pathogens (Young, 2009). Bioactive compounds that are abundant in milk and dairy products have importance in infant development, microbial activity including antibiotic and probiotic action, gastrointestinal activity, wellbeing, development and function, immunological development and function (Pieter et al., 2006).

During past decades, milk and milk industry have developed significantly due to the positive impacts of milk on human health and nutrition, and large number of bioactive compounds found in milk. It is important to understand the functions of milk ingredients to obtain high quality dairy products.

### 1.1.1 Milk proteins

There are two kinds of milk proteins, one being casein and the other one whey proteins (serum proteins). In general, whey proteins constitute 20%, on the other hand casein constitute 80% of milk proteins, however the proportion of whey proteins to the casein differs depending on the lactation stage. Whey protein content of milk that is produced in mid-lactation is lower than that of produced towards the end of lactation and in the first few days after calving, this phenomenon is explained by the elevated levels of blood serum proteins (Alan and Jane, 1996).

Milk proteins have very high nutritional value and are complementary with respect to the essential amino acid content. Although processing decreases the digestibility of milk proteins, they are digested easily (Alan and Jane, 1996).

#### 1.1.1.1 Casein Proteins

The casein proteins of milk can be subcategorized into five main groups, $\alpha_{s1}$-casein, $\alpha_{s2}$-casein, β-casein, γ-casein and κ-casein. Except γ-casein, all other four caseins are products of mammary gland gene, γ-casein is the product of post-translational proteolysis of β-casein. The proportions of casein proteins in milk may differ significantly from species to species of cow depending on the genetic variation of individual, however, stage of lactation does not cause significant change in the composition of casein proteins (Alan and Jane, 1996).

The caseins are globular proteins. Casein proteins are known to be good nutritive supply for owing worthful amino acids, and some minerals such as calcium and phosphate, they have been proven to be the source of biologically active compounds and bioactive peptides (Young, 2009).

Properties of casein are different than that of other proteins. Casein does not denature or hardly denatures, however heating above $120^0$C causes chemical changes which force casein to be insoluble. Caseins are hydrophobic. They have high charge which keeps them in solution. High charge of casein is a result of phosphate groups. Groups strongly bind to calcium ion (Pieter et. al., 2006).

κ-Casein have only one phosphate group. This feature makes κ-casein different from α- and β-caseins. κ-Casein molecules are composed of comparatively stable, single disulphide bonded structure (Alan and Jane, 1996).

α- and β- caseins are linked with the calcium phosphate by the aid of phosphoserine residues in the structure of calcium phosphate. The hydrophobic part of the κ-casein is attached to the core of micelle (Alan and Jane, 1996)

Micelles are the spherical much hydrated complexes that are formed when the caseins interact with each other and calcium phosphate (Alan and Jane, 1996). Casein micelles determine the stability of milk during processing such as heat treatment and storage. Their behavior is significant during cheese manufacturing. Micelles are determinants of rheological properties (Pieter et. al., 2006). There are contradictory models for the formation of casein micelle. The most satisfactory is the one in which casein micelles are of aggregate of spherical sub-micelles (Alan and Jane, 1996). If micelles aggregate, fat globules are entrapped in the gels formed. This happened during renneting and slow acidification (Pieter et. al., 2006).

#### 1.1.1.2 Whey proteins

Whey proteins of milk are composed of proteose-peptones which are partly derived from hydrolysis of β-casein, serum albumin, immunoglobulin (blood derived proteins), α-lactalbumins and β-lactoglobulins. The molecular weights of β-lactoglobulins, α-lactalbumins, serum albumin and immunoglobulin are 18300, 14000, 63000 and up to 1000000, respectively (Alan and Jane, 1996).

Whey proteins are composed of polar, nonpolar and charged residues in compact globular form (Alan and Jane, 1996). They have high hydrophobicity. If milk is heated, whey proteins become insoluble due to denaturation (Pieter et. al., 2006).

Whey proteins, in native state, do not interact with other proteins or do not aggregate strongly and this phenomenon is explained by the fact that disulphide bonds between cysteinyl residues are formed in which proteins undergo intramolecular folding which results in burning of most of the hydrophobic residues (Alan and Jane, 1996).

β-Lactoglobulin is the major whey protein. It has some functional and nutritional properties such as antioxidant activity, anticarcinogenic activity and other metabolic effects (Young, 2009).

Its characteristics dominate the properties of serum protein, especially reactions occur due to heat treatment (Pieter et. al., 2006). At $60^0$C and milk pH values, β-lactoglobulin becomes susceptible to denaturation by unfolding of the tertiary structure (Alan and Jane, 1996). Its solubility mainly depends on the pH and ionic strength (Pieter et. al., 2006).

α-Lactalbumin is in spherical shape and it is more heat stable than the β-lactoglobulin. α-lactalbumin is present in all lactose containing milks and it has an important function which serves as a modifier during biosynthesis of lactose (Alan and Jane, 1996).

α-Lactalbumin has binding site for Ca ion in which Ca binds and stabilize protein. In the case of Ca ion removal or decreasing the Ca ion concentration, protein is denaturized at relatively low temperatures (Pieter et. al., 2006).

Immunoglobulins are large glycoprotein molecules and antibodies in milk. G, M and A are the groups of immunoglobulins found in milk. Immunoglobulin G (IgG) prevents bacterial growth, on the other hand IgM serves as an antibody against polysaccharide groups in the cell wall of bacteria and acts against viruses. Little is known about the actions of IgG and IgA in milk. However, IgM is in great importance in milk because it prevents growth of Gram positive bacteria (Pieter et.al. 2006).

#### 1.1.1.3 Heat effect on milk proteins

When milk is heated covalent bonding through S-S- bindings may occur, depending on pH and temperature. Bonds with proteins of the fat globule membrane and with κ-casein and $\alpha_{s1}$-casein and bonds between some whey proteins are also affected. As a result, these fat globules become associated with some whey proteins (Pieter et. al., 2006).

Casein proteins are very heat stable. On the other hand, whey proteins are heat-sensitive; they undergo denaturation at $80^0$C. Denaturation is explained when the disulphide bonds are broken and randomized. One free sulphydryl group found in the β-lactoglobulin welcome the initiation of the disulphide exchange reaction which makes β-lactoglobulin less heat-stable compared to α-lactalbumin. Since interaction takes place between β-lactoglobulin and κ-casein, denaturation of the β-lactoglobulin is considered much more important at $100^0$C and higher temperatures (Alan and Jane, 1996).

The globular serum proteins of milk lose their biological activity such as enzyme or antibody, when they are heated. These changes are not seen on proteose-peptones, just like the caseins (Pieter et. al., 2006).

The surface characteristics of micelles are changed while κ-casein remains on the surface and interaction occurs with the exchange of thiodisulphide. These changes affect stability of micelles which have impact on the interaction of casein micelles with the calcium phosphate (Alan and Jane, 1996).

Preheating of the concentrated milk at $90^0$C increases the stability, however stability of unconcentrated milk is reduced. This may be explained by the calcium ion concentration reduction in unconcentrated milk. Heating more than 20 min at $140^0$C causes destabilization of casein micelles and gel formation (Alan and Jane, 1996).

### 1.1.2 Milk fat

Milk fat composition is very complex, it is composed of nearly 98% triacylglycerols with small amounts of monoacylglycerols diacylglycerols and free fatty acids. There are also small amounts of phospholipids, cholesterol and cholesterol esters and fat soluble vitamins such as vitamin A, D, E and with very small amount of vitamin K (Alan and Jane, 1996).

Lipid molecules are large spherical globules and they are surrounded by milk fat globule membrane. The diameter of globules increases as fat content of milk increases (Alan and Jane, 1996).

Milk fat is solvent for vitamin A, D and E and provides linoleic and linolenic acid, essential fatty acids (Pieter et. al., 2006).

Triacylglycerols also called triglycerides, consist 98% of fat milk and 95% of triacylglycerols are composed of 15 fatty acids.Bovine milk contains 8 saturated fatty acids that contain even number of carbon atoms, two odd-numbered saturated acids, dienes and trienes and three monounsaturated fatty acids. Depending on the stage of lactation and food source of animal, proportion of fatty acids differs. Normally 70% of total fatty acid, by weight is saturated fatty acids, 27% monounsaturates and 3% dienes and trienes. Even number carbon atom containing triacylglycerols consist much of milk fat (Alan and Jane, 1996).

The distribution of fatty acid residues in the triglyceride molecules affects the crystallization property of milk fat, most other properties rely on the composition of fatty acids (Pieter et. al., 2006).

Number, position and configuration of double bonds, chain length, branching, hydroxyl group and fatty aldehyde residue are main variables in determining fatty acids. The melting and crystallization characteristics of milk fat play crucial role in defining physical properties of dairy products that contain high amount of fat such as butter and ice-cream (Alan and Jane, 1996).

Fatty acids have varying melting points (Pieter et. al., 2006). Melting starts at -40$^0$C and finishes at +40$^0$C (Alan and Jane, 1996). Longer the chain length and less the number of double bonds, higher the melting point (Pieter et. al., 2006).

The fatty acids of phospholipids differ from other fatty acids of milk fat in terms of saturation degree and chain length. The fatty acids of phospholipids are more unsaturated and have longer chain length (Alan and Jane, 1996).

Compound lipids are also called polar lipids and most of them are phospholipids. They are polar since they contain acidic and/or basic groups. They are insoluble in the oil and as well as water (Pieter et. al., 2006).

Diglycerides are much like triglycerides in terms of their properties and they are nonpolar. Monoglycerides are polar and are surface active contrary to triglycerides. Lipolysis increases the amount of mono and diglycerides and free fatty acids (Pieter et. al., 2006).

Milk fat undergoes chemical reactions during storage. There are two major changes; oxidation and lipolysis (Alan and Jane, 1996). Considering shelf life of dairy products, oxidation is the major chemical change (Alan and Jane, 1996). Autoxidation of milk and dairy products generally initiates with the phospholipids of fat globule membrane. These lipids contain mostly unsaturated fatty acid residues (Pieter et. al., 2006). Oxygen reacts with unsaturated fatty acids and thus forms peroxides. Although peroxides do not have effect on the flavor of products, it decomposes and cause oxidative flavor, especially in products that have high fat content such as butter and cream (Alan and Jane, 1996). Early lactation milk is more likely to develop off flavor due to oxidation (Pieter et. al., 2006). Due to high saturation degree, milk fat is stable to oxidation, in addition antioxidants such as tocopherols and heat treatments such as UHT prevent oxidation (Alan and Jane, 1996).

When the triacylglycerols are hydrolyzed, fatty acids are released which is known as lipolysis. Lipases are responsible for hydrolysis of ester bonds. Heating may cause some changes in the fatty acid. Because of higher heating temperatures, position of double bonds alters and fatty acids transform from *cis* to *trans* (Pieter et. al., 2006). In processed dairy products heat stable enzymes of microbial origin are responsible for lipolysis, and hygiene control have led to fewer lipolytic rancidity (Alan and Jane, 1996).

### 1.1.3 Lactose

Lactose is a disaccharide that is composed of two monosaccharide; α-D-glucose and β-D-galactose (Alan and Jane, 1996). The chemical formula of lactose is $C_{12}H_{22}O_{11}$ (Alan and Jane, 1996). α-D-glucose and β-D-galactose are connected to each other by the β-1→4 glycosidic linkage. Lactose is a reducing sugar and it is unique to milk (Pieter et. al., 2006).

The concentration of lactose in milk differs from 4.2 to 5.0 %. Lactose concentration of udder disease suffering animals and late lactation milk is low, generally. There are three solid forms of lactose, α-lactose monohydride and anhydrous α- and β-lactose. β-Form has higher solubility compared to others. Lactose has one of the lowest solubility among sugars. This solubility has some results in concentrated milk and frozen dairy product production. In order to avoid sandiness, it is important to give rise to small crystal production in large number (Alan and Jane, 1996).

Sucrose solution is 3 times sweeter than lactose. In addition sweetness of milk is prevented by the casein protein. If lactose is converted to glucose and galactose, milk tastes sweeter. That is why lactose free milk is sweeter compared to lactose containing milk (Pieter et. al., 2006).

Lactose has contributions to the osmotic pressure, freezing point depression and boiling point elevation properties of milk, for example lactose stands 50% of osmotic pressure of milk (Alan and Jane, 1996).

Lactose has protein stabilizing characteristics and low sweetness. For these reasons, it is considered as food ingredient. Lactose may also be used for sucrose replacer in icings in order to decrease sweetness. In addition lactose may be used to prevent Maillard browning reaction in bakery technology, for example in biscuit production (Alan and Jane, 1996).

Lactose is a good source of energy and supposed to increase calcium absorption. However, lactose intolerance, inability to digest lactose, interferes with the use of lactose widely. Lactose intolerance degree changes from person to person and consequently symptoms (Alan and Jane, 1996). Lactose is hydrolyzed by lactase, more precisely β-galactosidase. Lactase is secreted in the small intestine. Individuals lacking this enzyme suffer lactose intolerance (Pieter et. al., 2006).

During heating, lactose is subjected to change in flavor, color, nutritive value. In addition lactose may transform in to other sugars and/or degrade to glucose and galactose. Isomerization of lactose to other sugars is reversible. The most important reaction taking place is Maillard reaction but the features of this process are not fully understood. The composition of milk, the amount of reactants and possibility of presence of active catalysts affect the reaction during heat treatment. To sum up, it can be stated that lactose is decomposed through isomerization reactions and a small amount is degraded by Maillard reactions during heating, however at higher temperatures Maillard reaction becomes much more important (Pieter et. al., 2006).

## 1.2 Hydrocolloids used in dairy desserts

Ingredients are very important in manufacturing of dairy desserts. Fat content of milk has the functions of providing flavor, body and texture, milk solids provide body, texture and contribute to sweetness. Added ingredients such as emulsifiers improve whipping quality and texture, stabilizers contribute to texture, melting qualities, air incorporation and viscosity.

Hydrocolloids are the food additives that are added to food products in order to manipulate the physical, textural and rheological properties of food products. Hydrocolloids are the polymers of animal, plant, microbial or synthetic origin. All hydrocolloids interact with water and stabilize. Hydrocolloid interaction with water depends on hydrogen bonding and thus on temperature (Martin, 2014).

Some hydrocolloids require heat in order to dissolve. The temperature needed for achieving maximum viscosity, gel strength or the stability of food product varies depending on the ingredients, especially on the ions. Although it is important to achieve full functionality by high temperature, it should be considered that high temperature may degrade some hydrocolloids, for example guar gum. Carrageenan may be degraded in the combination of high temperature and acid. Therefore, heating should be adequate to achieve full characteristics of hydrocolloids, but not so high that viscosity decreases due to partial hydrolysis of the hydrocolloids (Thomas, 2011).

Hydrocolloids affect the texture, stability, viscosity and flavors of foods. They may also have impact on the color and appearance. One major effect of hydrocolloids is the increase in opacity in foods. If the food product is considered best quality when it is transparent, carrageenan, xanthan and alginate are transparent versions of gums that can be used (Thomas, 2011).

There are several hydrocolloids, the most commonly used ones are: guar gum, xanthan gum, gum arabic, carrageenan, agar, alginate, cellulose, gelatin, locust bean gum and pectin (Martin, 2014). Gums are widely used as stabilizers in dairy desserts. Locust and guar gum are main gum type stabilizers. Guar gum has an advantage over locust gum. It is easily hydrated in cold water, however locust gum requires keeping at $70^0$C for 15 min and it is not suitable for UHT or HTST. Xanthan gum is also used as a stabilizer (Alan and Jane, 1996).

### 1.2.1 Cellulosics

Cellulose is found in the cell wall of the plants. It is a carbohydrate and the most abundant organic compound on Earth. It has high molecular weight and is composed of β-D-glucopyranosyl joined by glycosidic linkage. Cellulose is insoluble, however certain derivatives such as carboxymethylcellulose (CMC), methylcellulose (MC) and hydroxylpropylcellulose (HPMC) are water soluble and are used as food gums (Roy and James, 1999).

CMC is a widely used as a food gum (Roy and James, 1999). It is derived by the reaction of alkali and chloroacetic acid. It dissolves rapidly in cold water and they are used to control viscosity without gelling (Martin, 2014). Major characteristics of CMC are film forming, water binding, thickening agent and retardation of sugar crystallization, prevention of syneresis and stabilization of proteins (Roy and James, 1999).

Hydroxypropyl substitution is done by the reaction of propylene oxide and methyl chloride. MC and HPMC are both cold-water soluble. They are used for thermal gelation, fat reduction, forming emulsions and foams (Roy and James, 1999).

### 1.2.2 Guar gum

Guar gum is an important thickening polysaccharide for food. Guaran is the polysaccharide of guar gum and makes up 80-85% of commercial guar. When guar gum is dispersed in water, it hydrates and builds viscosity rapidly. Guar gum is compatible with most other foods since it is neutral. Guar gum interacts with starch, κ-carrageenan, agar and xanthan gum. This interaction results in high viscosity (Roy and James, 1999).

Guar gum is used as an economical thickening agent in food industry. It is mainly applied in dairy products, bakery products, sauces, pet foods and prepared meals. It may be used for different purposes in different types of food products. For example, in ice cream production guar gum is used to prevent ice crystal growth, to improve mouth feel, and to reduce chewiness. In cheese production, guar gum significantly reduces syneresis. It improves mixing of ingredients in bakery products and improves shelf life (Roy and James, 1999).

### 1.2.3 Xanthan

Microorganisms produce polysaccharides to maintain structure and protect coating against other organisms and also prevent water loss when water supply diminishes. *Xanthomonas campestris* is a bacterium which is mostly found on leaves, produces a polysaccharide called xanthan that encapsulates the cell and diffuses into surroundings. Xanthan is used as a food gum (Roy and James, 1999).

The structure of xanthan is similar to the cellulose. Xanthan has extraordinary stability to heat, acid and alkali. Xanthan solutions have high viscosity because of their stiffness that makes xanthan molecules extend in the solution. Low shear rates do not decrease viscosity of xanthan solutions and these characteristics make xanthan perfect for making suspensions and emulsions. Xanthan solutions do not thicken upon cooling, which make xanthan perfect for salad dressings and chocolate syrup. In regular salad dressing, it is both thickener and stabilizer at the same time for both oil- in-water emulsion and suspension of spices (Roy and James, 1999).

### 1.2.4 Carrageenan

Carrageenan is obtained from red seaweeds by extraction with hot and dilute alkaline solution. This extraction gives sodium carrageenate. Carrageenan molecules are composed of linear chains of D-galactopyranosyl units joined with either $(1\rightarrow 3)$-α-D- and $(1\rightarrow 4)$-α-D- glycosidic linkages. There are three kinds of carrageenan: kappa (κ), iota (ι) and lambda (λ). Carrageenan produces highly viscous solutions when dissolved. Viscosity is stable over a range of pH values (Roy and James, 1999).

κ-Carrageenan forms very strong gel in the presence of potassium ions. Calcium ions are less effective in producing gelation. κ-Carrageenan is the strongest and stiffest of carrageenan gels. Iota type of carrageenan is more soluble compared to κ- type. In addition, iota type of carrageenan forms stronger gels with calcium ions. The gels are elastic and resilient. I-carrageenan is more hydrophilic compared to κ-carrageenan. All salts of λ-carrageenan is more soluble and non-gelling (Roy and James, 1999).

Carrageenan gums are mostly used with milk and milk products and water. They do not need refrigeration since they do not melt at room temperature, in addition they are relatively freeze-thaw stable. Carrageenan reacts with proteins, especially with the milk's. κ-carrageenan forms complex with casein micelles of milk. The thickening effect of κ-carrageenan is 5-10 times weaker in water, than in milk. Carrageenan is also used as a second replacer in ice-cream manufacturing to prevent whey phase separation (Roy and James, 1999). Incorporation of κ-casein micelles with κ-carrageenan due to ion interaction is the reason of prevention of whey phase separation (Martin, 2014).

### 1.2.5 Pectin

Natural pectin are found in the cell wall and in the intracellular layers of all plants, on the other hand, commercial pectin is galacturonoglycans with various contents of methyl ester groups. Pectin is used in the jam and jelly production, confectionary, beverage and acidified drink industry. It is stable at low pH values, so it is perfect for use in acidified foods (Roy and James, 1999).

### 1.2.6 Gum arabic

Gum arabic is also called gum acacia, since it is produced from acacia tree exudates. It contains some minerals like, calcium, magnesium and potassium. Gum arabic is neutral or acidic a little bit. It consists of two fractions: polysaccharide chains and molecules that have protein as a part of their structure (Roy and James, 1999).

Gum arabic easily dissolves in water. It is a unique gum that has high solubility and low viscosity. Addition of electrolytes to a gum arabic solution results in decrease in the viscosity. Increasing cation amount also causes decrease in the viscosity (Martin, 1969). Gum arabic is good emulsifying and stabilizer agent (Roy and James, 1999). This type of gum  has probiotic promoting beneficial effects (Martin C., 2014). Gum arabic forms a thick layer on the droplets and these characteristics are used for encapsulation. It has use in caramel, toffee, pastilles, cocktail mix, fruit juice and soft drink production (Roy and James, 1999).

### 1.2.7 Starch

Starch is a unique carbohydrate according to its chemical and physical characteristics. It serves 70-80 % of calories consumed by human. Commercial starches are obtained from potato, wheat, cassava, waxy corn and high-amylose corn. These starch and modified starch products have important functions such as texturizing, gelling, moisture retention and binding in food industry (Roy and James, 1999). Starch is a versatile product. There are numerous products that are modified which increased starch use and utility (James and Roy, 2009).

Starches contain various amounts of amylopectin and amylose which define their characteristics. Amylopectin is a very large and branched molecule. An amylopectin chain is mostly and mainly composed of C chain that carries one reducing end group termed B chains, to layer that A chains are attached. Structure, average molecular weight and molecular weight of amylopectin is dependent on the source of it. Amylose is essentially a linear chain of (1-4)-linked α-D-glucopyranosyl units and some (1-6) α-D-glucopyranosyl branches. The branches of amylose molecules are either short or long. This variety in length allows molecules to act as essential linear polymers, thus forming strong films and fibers and retrograde easily. Amylose molecules have right-handed spiral or helical shape. The helix form makes amylose films and fibers more elastic than cellulose. Unmodified starches for example, rice, wheat and corn starch contain 70-80% amylopectin and 20-30% amylose (James and Roy, 2009). Waxy maize starch contains less than 1% amylose, corn starch about 28% amylose, high amylose corn starch about 50-70%, potato starch 21% and wheat starch 28% amylose (Roy and James, 1999).

Waxy corn starch, which is also called waxy maize starch, is mostly composed of amylopectin molecules, which gives to different and useful properties. When waxy maize is cooked, it gives high viscosity and clear appearance. Since it is free of amylose, it shows resistance to gel formation and syneresis during cold storage. Waxy maize starches are different from degrees of branching and chain lengths point of view. Cross linked waxy maize starch has excellent thickening, clarity and processing tolerance abilities. Waxy maize starch is said to have better taste compared to dent corn starch (James and Roy, 2009).

High amylose corn starch is used to give high strength gels to give shape and integrity to the product. These gels form brittle, tough and strong films. High amylose starches are used for increasing crispness. They have usage in cheese production to replace caseinate, whipping agent and fat replacer in aerated confections such as nougats and thickeners to delay swelling in retorted puddings.

Potato starch is mostly used in Europe. Potato starch dissolves more rapidly compared to other cereal starches. Potato starch granules are large and swell. Potato starch causes high viscosity and grainy appearance. Cereal starches are more sensitive to shear compared to others. Potato starch paste are being clear, however they are exposed to syneresis easily especially when frozen. It contains 20% amylose and it is used as a gelling agent in confections, thickener in a paste technology, pie filling and in instant puddings (James and Roy, 2009).

Wheat starch is isolated from wheat flour and it is a by-product of gluten manufacture. Wheat starch production consists 20% of total starch production. Wheat starch granules are in different size distribution. The viscosity and gel strength of pastes of wheat starch is lower than those of corn starch, however the rheological properties are similar. Wheat starch has greater freeze-thaw stability than tapioca starch and less than waxy maize starch. Wheat starch is used in baking technology. It is also strong emulsifying agent in certain food products and used in confectionary products such as Turkish delight (James and Roy, 2009).

Rice starch has various types from sticky, non- gelling waxy types to intermediate amylose containing types. These varieties cause texture differences in food products.

Texture content is controlled by the amylose content and amylose content is determined by the genetic background. Rice starch granules are differentiated in the size. Dusting powders of cosmetics and bakery industry take advantage of small granule size of rice starch. Rice starch produces films with tender crispness and has special mouthful properties and that is why they are used in batter, ice cream and as coatings and glazing agents for nut meats and candies (James and Roy, 2009).

## 1.3 Studies on dairy desserts

There are several researches in literature about textural, rheological and sensorial properties of dairy desserts. The effect of different concentrations of κ-carrageenan, native maize starch and milk proteins on the milk desserts have been studied by changing the amount of water in order to measure the influence of water content on the physicochemical and rheological properties of dairy desserts (Depypere et. al., 2002). It has been concluded that water content significantly affect the rheological and textural properties. Verbeken et. al., (2006) have studied the effect of different concentrations of carrageenan, milk powder and starch while keeping sugar and water concentration constant, on the gel strength, syneresis and rheology of sterilized dairy desserts. They have concluded that starch has greater effect on complex modulus while milk proteins have contributed to the gel strength. It has also been shown that exclusion effect of starch significantly affected rheological properties of desserts. In another study, sensory and physical properties of frozen desserts have been studied (Specter and Setser, 1994). In this study, effect of milk fat and sucrose addition has been studied. Another study reveals the rheological properties of starch-sugar-protein mixture during heating and cooling process (Yang et. al., 2004). Lethuaut et. al., (2004) have studied the flavor perception and aroma release of dairy desserts. Tarrega and Costell (2006) have studied the effect of inulin addition to dairy desserts that contained different amount of starch by measuring sensory and rheological properties. Inulin addition contributed to creaminess, sweetness and thickness and increased the storage modulus and complex viscosity. Tarrega and Costell (2006) have studied rheological and sensory properties of semi-solid desserts. Gonzalez-Tomas and Costell (2006) have studied color and texture of eight different commercial dairy desserts. Gonzalez-Tomas et. al., (2008) have also studied the rheology, flavour release and perception of low-fat dairy desserts. Doublier and Durand (2008) characterized rheological properties of semi-solid dairy desserts. Effect of guar gum and date syrup as a sugar replacer of frozen dairy dessert on rheological, sensory and physicochemical properties has been the subject of the study of Milani and Koocheki (2011). Vidigal et. al., (2012) have studied the effect of whey protein concentrate on the textural, rheological and sensorial properties of dairy desserts. Whey protein concentrate addition increased the textural properties (chewiness, firmness, elasticity and gumminess), promoted stronger gel formation as a result of protein-protein interaction and increased yield stress and apparent viscosity of desserts. Influence of different gums and their combinations on rheological properties of dairy desserts has been studied by Toker et. al., (2013). Study revealed that alginate has less effect on the rheology of desserts while combinations which contained κ-carrageenan had significant effect.

## 1.4 Lactose intolerance

Lactose intolerance, which is also called lactose nonpersistence, is the inability to digest lactose (EFSA, 2010). Lactose is hydrolyzed by the action of lactase enzyme into glucose and galactose, which are absorbed by human digestive system. In the case of low lactase activity or absence of lactase enzyme, lactose intolerance symptoms are observed.

Although rarely seen, lactose intolerance may be fatal. In addition, lactose intolerance causes discomfort and disrupted life quality (Heyman, 2006).

Symptoms of lactose intolerance are as follows: abdominal pain, diarrhea, nausea, flatulence and bloating. The symptoms and the intense of symptoms differ from person to person depending on the amount of lactose consumed, lactase deficiency and the type of food (Heyman, 2006).

The definitions used by American Academy of Pediatrics Committee on Nutrition are as follows:

- Lactose intolerance, is a digestive disease in which if any of diarrhea, nausea, flatulence, abdominal pain and /or bloating occurs when lactose containing food is consumed
- Lactose malabsorption is the term used to describe when the amount of lactase enzyme is not enough for hydrolysis of lactose
- Primary lactase deficiency is attributed to the absence of lactase that develops during childhood. It is the most common cause of lactose intolerance and lactose malabsorption.
- Secondary lactase deficiency is the case when small bowel injury occurs and this results in lactase deficiency
- Congenital lactase deficiency is seen in newborn children. When they consume lactose containing food, it causes intractable diarrhea and causes too much water and electrolyte loss.
- Developmental lactase deficiency is the case when infants less than 34 weeks suffer relative lactase deficiency

Almost 70% of world adult population suffers lactose intolerance (EFSA, 2010). Ethnicity is an important factor in lactose intolerance, since different ethnics have different frequencies of lactose intolerance (Lomer, et. al., 2007). In Europe, 4 to 56% of people are lactose intolerant. Frequency of lactose intolerance in European countries are as follow: Austria 20 %, Britain 23%, Denmark 4%, Estonia 43%, Finland 17%, France 38%, Germany 14%, Greece 46%, Hungary 40%, Ireland 4%, Italy 56%, Poland 37% and Spain 34% (EFSA, 2010). Europe has the lowest lactose intolerance incidence among populations. In North America, nearly 79% of adults of Native Americans, 75% of blacks, 51% of Hispanics and 21% of Caucasians are found to be lactose intolerant (Schrimshaw et. al, 1988). Lactose intolerance is 37%, 91%, 86%, in Turkey, South Africa, and Iraq, respectively (Bayhan et. al, 1993).

It is not possible to cure lactose intolerance but its symptoms can be controlled (Chris, 2011). Therapy of lactose intolerance is possible by removing lactose from diet. According to the research conducted by American Pediatric Academy in 1998, soy based product usage may help to regulate primary lactose deficiency, however for babies less than 1800 g soy based products are not recommended. In addition, in order to cure and prevent abdominal pain, regular use of soy is not suggested (Klish et. al., 1998). Another option for lactose intolerance people is lactase tablets. Lactase tablets are swallowed while eating lactose containing food, but it is not a good option says Dr. Heaney since it is expensive (Emily, 2010).

Production of lactose free products is a new trend for food industry. By hydrolyzing lactose, it is possible to produce lactose free products. Lactose hydrolyzing makes it possible to create market diversity, to decrease energy expenses and to prevent sandy texture originated from lactose. By hydrolyzing, lactose is broken down in to glucose and galactose. Aim of hydrolyzing is to make lactose digestible and accomplished by two ways: acidic and enzymatic hydrolyzing. In acidic hydrolyzing by the aid of acid solution, pH of medium is brought between 1-2 at $150^0$C and reaction takes place quickly. Since temperature is high secondary reactions take place between acids, proteins and lipids and that result in sensorial change which is undesired situation. On the other hand, in enzymatic hydrolyzing no change is observed at the final product flavor and nutrition. In industry, only microorganism originated enzymes are used. The problem in enzymatic hydrolysis is the cost of enzymes. By using more stable enzymes, these problems are reduced (Ladero et al., 2001; Tanrıseven and Doğan, 2002; Numanoglu and Sungur, 2004).

## 1.5 Aim of the study

Dairy dessert is much consumed and preferred product in the world due to its taste and availability. There are too many types of dairy desserts such as ice cream, sherbet, pudding, frozen yoghurt and so on. Dairy desserts are also famous in Turkey. In addition to the products mentioned above, there are traditional dairy desserts such as muhallebi, sütlaç, kazandibi, tavuk göğsü, keşkül, güllaç, sütlü nuriye. These products are widely consumed. However, lactose intolerant people cannot consume these desserts. That is why it is required to develop lactose free dairy desserts for people suffering lactose intolerance.

It is likely that dairy dessert without lactose will have different physical properties than lactose containing dessert due to the complex interactions among different components. In literature, there are researches on the effects of gums, inulin and their interactions on the rheological properties of dairy desserts, and quality of low-fat dairy desserts. However, there is inadequate information and research in the literature based on lactose free dairy dessert production. That is why lactose free dairy dessert production is a promising and significant study. The main purpose of this study is to produce lactose free dairy dessert for lactose intolerant people. Studying on lactose free dairy dessert is important not just because there is lack of studies and information about it, but also in order to make market range and diversity and supply people with dairy dessert who suffer lactose intolerance so that patients will feel comfortable while eating dairy dessert. In this study, lactose free dairy dessert is formulated with different types and concentrations of gums (κ-carrageenan, guar, gum arabic) and various concentrations of sugar and finally two types of starch (waxy maize and amylo maize) to obtain product with acceptable quality.

# CHAPTER 2

# MATERIALS AND METHODS

## 2.1 Materials

All the ingredients used for dessert production was obtained from local markets except starch. For the dessert production, semi skimmed milk was used. The fat content in both lactose containing and lactose free milk was 1.7 %.For the lactose free dairy dessert, lactose free milk was used. Effects of two types of starches, which were waxy maize starch (Firm-Tex$^{TM}$, National Starch and Chemical Company, USA) and amylo maize starch (Hylon Film$^{TM}$, National Starch and Chemical Company, USA) and three types of gums, which were arabic gum (Sigma-Aldrich), guar gum (Sigma-Aldrich) and κ-carrageenan (Fluka) on product quality were studied.

## 2.2 Preparation of lactose containing dessert

Different amounts of starch was added to 250 ml milk and stirred by magnetic stirrer (Heidolph Instruments, MR3001K, Schwabach, Germany) at 500 rpm during cooking. The concentration of starch added varies according to the type of the starch. For waxy maize starch, the concentration was 0.032g/ml, 0.04g/ml and 0.048g/ml, on the other hand for amylo maize starch, it was 0.064g/ml, 0.072g/ml and 0.08g/ml. The temperature of hot plate was arranged to 250°C and mixture cooked for 35 min. After 25 min sucrose was added to the dessert at a concentration of 0.14 g/ml and was cooked for another 10 min. At the end of cooking, dessert was poured into 100 ml beakers, closed with a stretch film and stored in the refrigerator for one day. Next day, samples were analyzed in terms of texture and rheology. For the color and NMR experiments, samples were poured into cuvettes while they were still hot and the analysis was done after cooling to room temperature.

### 2.3 Preparation of lactose free dessert

After starch was added to 250 ml milk, it was heated using hot plate (Heidolph Instruments, MR3001K, Schwabach, Germany) at 250°C for 35 min and at the same time stirred at 500 rpm. Different concentrations of starch were used for the preparation of the dessert: 0.032 g/ml, 0.040 g/ml and 0.048 g/ml for waxy maize and 0.064 g/ml, 0.072 g/ml and 0.080 g/ml for amylo maize starch. Since lactose free milk is sweeter, the effect of lower sucrose concentration (0.1g/ml) was also studied in addition to sucrose at a concentration of 0.14g/ml. Furthermore different gum types (guar gum, arabic gum and κ-carrageenan) was also added in order to see the effect of gum on physical properties of desserts. Gums were added in two different concentrations (0.5% and 1% on dry solid base of dessert) at the 10th min of cooking so that mixing of gum was easier before the dessert gets viscous. After 25 min, sucrose was added and cooked for further 10 min and then poured in to beakers or cuvettes to be left for cooling.

### 2.4 Measurement of texture of dessert

Textural analysis was performed by TA plus Texture analyzer device (Lloyd Instruments Ltd., England) by 20mm diameter cylindrical probe. Penetration tests were carried at a 2mm/s constant rate connected to 50N load cell. Sample in 100 ml beakers having height of 40 mm was used for the analysis. Penetration was continued until it reaches the 25% of initial height and for each formulation test was conducted at least 6 times. Cohesiveness and firmness values of desserts were measured. Cohesiveness of food is the net work applied in the non recoverable part of food during chewing. Firmness of food is the net force required to penetrate the 25% of food by height. Measurements were conducted at room temperature.

## 2.5 Color measurement

Color measurements were conducted by Shimadzu spectroscopy (Kyoto, Japan). Before measurements machine was set a baseline using the $BaSO_4$ white plate. The sample was poured into small cuvettes while it was hot and then their color values were measured. The results were reported in CIE L* a* b* units. L* value stands for brightness of sample and it is the measurement of luminosity that takes values between 0 and 100 (0=black to 100=white). The value of a* (- = green to + = red) and b* (- = blue to + = yellow) refers to reddish and yellowish colors, respectively.

## 2.6 Rheology measurement

Rheological properties of desserts were measured by using Kinexus rheometer (Malvern Instruments Ltd., United Kingdom). Measurements were done at $25^0$C which is controlled by passive heat exchanger (Malvern Instruments Ltd., USA) connected to rheometer. Cone and plate configuration (Malvern Instruments Ltd., United Kingdom) with 40 mm diameter and 1 mm gap between cone and plate was used to conduct rheological measurements.

### 2.6.1 Steady shear data

Measurements were carried out at shear rate range of 1-100 $s^{-1}$. A total 31 points were recorded during 120s measurement time. During measurement, shear stress versus shear rate values were recorded.

### 2.6.2 Viscoelastic properties

Frequency sweeps were performed over the range of f=10-0.1 Hz, shear strain was 0.5% during measurements and the values of storage modulus ($G^{'}$), loss modulus (G") were determined.

### 2.7 Relaxation time measurements

The spin-spin measurements of desserts were measured by Low resolution NMR device (Russia). A Car-Purcell-Meiboom-Gill Pulse (CPMG) sequence was used with an echo time 900ms, 8 acquisition points, 800 echo and 16 scans. The desserts were poured into cylindrical test tubes up to 16mm while they were hot. Measurements were done after cooling to room temperature. As a reference liquid for T2 measurement glycerol was used. Three samples were measured and each measurement was repeated two times.

### 2.8 Sensory analyses

Sensory analysis of desserts was performed by hedonic ranking test by 15 panelists (Resurreccion, 2008). 5-point ranking scale was used in the tests. Different dessert formulations were evaluated in terms of acceptability. Ranking scale was defined from 1 to 5 which were Like extremely (=5), Like moderately (=4), Neither like or dislike (=3), Dislike moderately (=2), Dislike extremely (=1). In addition, panelists have been asked comments about their opinions about desserts and how they found it.

### 2.9 Statistical Analyses

The results obtained from textural analysis, colorimeter, and sensory analysis were statistically analyzed by one way and two way analysis of variance (ANOVA) in order to observe the effect of gum type, gum concentration, and starch type and starch concentration on quality parameters of desserts. For comparison of parameters Tukey's comparison test was used ($p \leq 0.05$).

# CHAPTER 3

# RESULTS AND DISCUSSION

## 3.1 Color analysis of desserts

In general, color values of different dessert formulations were close to each other (Table 1-2). In gum free desserts, as the starch amount increases $L^*$ decreases slightly. Lightness values of waxy maize and amylomaize containing desserts were in the range of 63.31-75.23 and 70.20-76.72, respectively. This implies that lightness of amylomaize starch containing desserts were slightly higher than waxy maize containing ones. The $a^*$ values of waxy maize containing desserts were between -3.72 and -2 while the $a^*$ for amylomaize containing desserts were between -3.53 and -2.55. Values of $b^*$ made by waxy maize and amylomaize starches varied between -3.23-1.85 and -4.01-2.47, respectively. Granato and Masson (2010) have reported lightness values of soy based desserts between 75-79.

**Table 1**. Color values of desserts that contain waxy maize starch

| Dessert Formulation | 0.032 g/ml waxy maize | | | 0.040 g/ml waxy maize | | | 0.048 g/ml waxy maize | | |
|---|---|---|---|---|---|---|---|---|---|
| | L* | a* | b* | L* | a* | b* | L* | a* | b* |
| LC[a]+0.14 g/ml S[c] | 74.28 | -3.54 | 0.80 | 70.68 | -3.69 | -0.7 | 68.04 | -3.20 | -2.4 |
| LF[b]+0.10g/ml S | 70.97 | -3.44 | 0.20 | 67.98 | -3.16 | -2.4 | 63.31 | -2.18 | 0.47 |
| LF+0.14g/ml S | 70.66 | -3.48 | -0.36 | 69.23 | -3.28 | -0.7 | 64.58 | -2.00 | 1.08 |
| LF+1% GG[d] | 71.58 | -3.54 | -0.03 | 67.90 | -3.22 | -1.4 | 69.00 | -3.55 | 0.79 |
| LF+0.5% GG | 70.36 | -3.61 | -0.88 | 68.32 | -2.87 | -3.2 | 71.99 | -2.88 | 1.63 |
| LF+1% AG[e] | 75.23 | -3.72 | 0.30 | 67.6 | -3.41 | -1.6 | 69.65 | -3.42 | 1.70 |
| LF+0.5% AG | 74.54 | -2.97 | 1.85 | 69.38 | -3.40 | -1.1 | 69.92 | -2.90 | 1.14 |
| LF+1% KC[f] | 67.95 | -3.31 | -3.03 | 65.83 | -3.17 | -2.4 | 67.77 | -3.56 | 0.26 |
| LF+0.5% KC | 73.24 | -3.59 | 0.01 | 66.05 | -3.14 | -2.9 | 70.78 | -2.82 | 0.81 |

[a]Lactose containing milk

[b]Lactose free milk

[c]Sucrose

[d]Guar gum

[e]Gum arabic

[f]κ-carrageenan

**Table 2.** Color values of desserts that contain amylomaize starch

| Dessert Formulation | 0.064 g/ml amylomaize | | | 0.072 g/ml amylomaize | | | 0.080 g/ml amylomaize | | |
|---|---|---|---|---|---|---|---|---|---|
| | L* | a* | b* | L* | a* | b* | L* | a* | b* |
| LC[a]+0.14 g/ml S[c] | 76.72 | -2.82 | 2.77 | 74.30 | -2.94 | 2.43 | 73.93 | -2.87 | 2.70 |
| LF[b]+0.10g/ml S | 75.37 | -3.03 | 2.75 | 74.95 | -2.98 | 2.82 | 73.23 | -3.17 | 2.12 |
| LF+0.14g/ml S | 75.45 | -3.18 | 2.29 | 70.74 | -3.10 | 2.03 | 70.20 | -3.13 | 2.04 |
| LF+1% GG[d] | 73.80 | -3.40 | 1.18 | 72.87 | -3.27 | 2.44 | 71.48 | -3.13 | 1.72 |
| LF+0.5% GG | 72.65 | -3.20 | 1.78 | 73.35 | -2.56 | 4.01 | 70.24 | -2.73 | 2.02 |
| LF+1% AG[e] | 74.68 | -3.27 | -2.47 | 73.22 | -2.75 | 3.59 | 72.19 | -3.18 | 2.13 |
| LF+0.5% AG | 74.59 | -3.17 | 2.39 | 74.59 | -3.17 | 2.39 | 71.64 | -3.06 | 2.08 |
| LF+1% KC[f] | 75.61 | -2.83 | 2.70 | 72.38 | -2.96 | 1.93 | 71.37 | -2.55 | 3.49 |
| LF+0.5% KC | 71.67 | -3.53 | 0.53 | 74.35 | -3.24 | 2.21 | 71.86 | -2.74 | 3.46 |

[a]Lactose containing milk

[b]Lactose free milk

[c]Sucrose

[d]Guar gum

[e]Gum arabic

[f]κ-carrageenan

### 3.2 Texture profile analysis

In this study, two types of starches, which were waxy maize (99% amylopectin) and amylomaize (63% amylose), were used. Cohesiveness is attributed to amylopectin (Karam et. al., 2005) and firmness to amylose (Propokowich and Biliaderis, 1995).

Therefore, difference in textural properties of dairy desserts made with waxy maize and amylomaize starches is expected. More amylomaize was required to be used as compared to waxy maize in order to get viscous gel like body. As the fraction of swollen starch increases, mixtures get more viscous. Swelling capacity of starch is attributed to the water uptake and solubility of starches. As the amylose content of starch increases water uptake and solubility of starch decreases. That is why more amylomaize was required to get viscous product. Therefore, it was not possible to work with the same concentrations in two different starches.

### 3.2.1 Effect of sucrose and starch concentration on texture of lactose free dairy desserts

Increase in starch concentration in both amylomaize and waxy maize containing desserts increased textural parameters (Figures 1-4). Increasing waxy maize starch concentration led to the increase in the amylopectin which contributed to texture of desserts. On the other hand, when amylomaize starch concentration increased, free amylose content increased which is important factor in providing texture to the products.

Two way Anova analysis shows that, in both waxy maize and amylomaize containing lactose free desserts, sucrose concentration causes significant difference in the texture of desserts.

Textural properties (cohesiveness and firmness) of waxy maize containing lactose free desserts decreased as the sucrose concentration increased (Figures 1 and 2). On the other hand, higher amount of sucrose addition to the amylomaize containing desserts caused increase in the textural properties (cohesiveness and firmness) of desserts (Figures 3 and 4). Spies and Hoseney (1982) stated that sucrose restricts chain's flexibility by the stabilization of amorphous regions by interacting with the amylopectin. Sucrose forms bonds with the amylopectin molecules of the starch. It is known that sucrose delays gelatinization by sucrose-starch interaction. Increasing gelatinization temperature of starches by the addition of sucrose has been studied widely (Spies and Hoseney, 1982; Kohyama and Nishinari, 1991; Kim and Walker, 1992). It has been showed that addition of sucrose increases gelatinization temperature thus delays gelatinization of starches since it binds water and decreases the required water for gelatinization. However, this may not express the results in this study since gelatinization is most probably completed before the addition of sugar. The decrease in texture of waxy maize containing desserts with the addition of sucrose may be explained by retardation of retrogradation. Sucrose may bind amylopectin and prevent retrogradation. Miles et. al., (1985) has reported that retrogradation process consists of two steps, first one is the amylose gelation during gelatinization, second one is the recrystallization of amylopectin (Kohyoma and Nishinari, 1991). Kohyoma and Nishinari (1991) and Babic et. al., (2011) observed in their study that sucrose prevents retrogradation of corn starches by interacting amylopectin molecules to stabilize starch matrix and finally inhibit starch retrogradation.

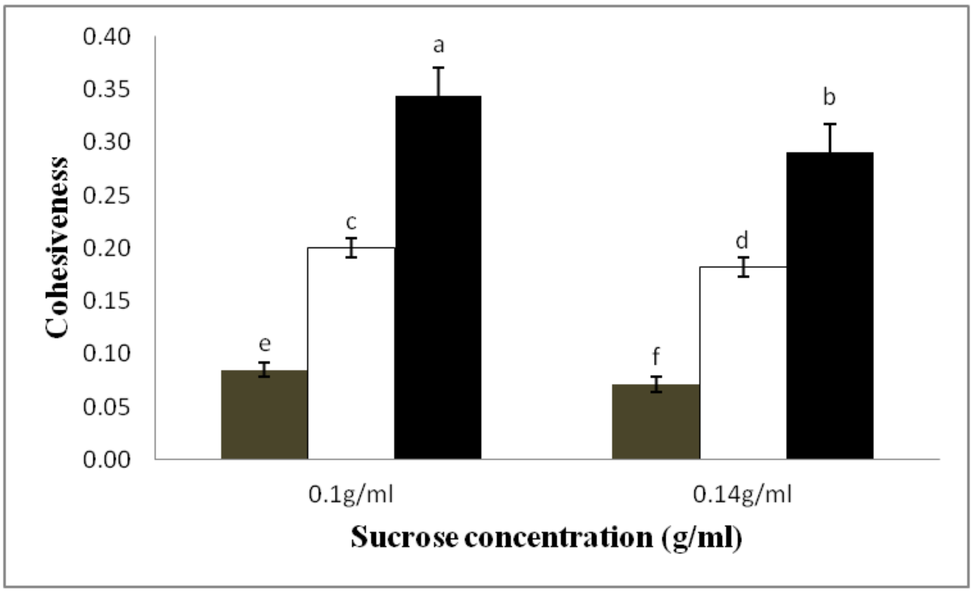



**Figure 1.** Cohesiveness values of lactose free desserts containing different waxy maize and sucrose concentrations (gray-0.032 g/ml, white-0.040 g/ml and black-0.048 g/ml waxy maize starch)

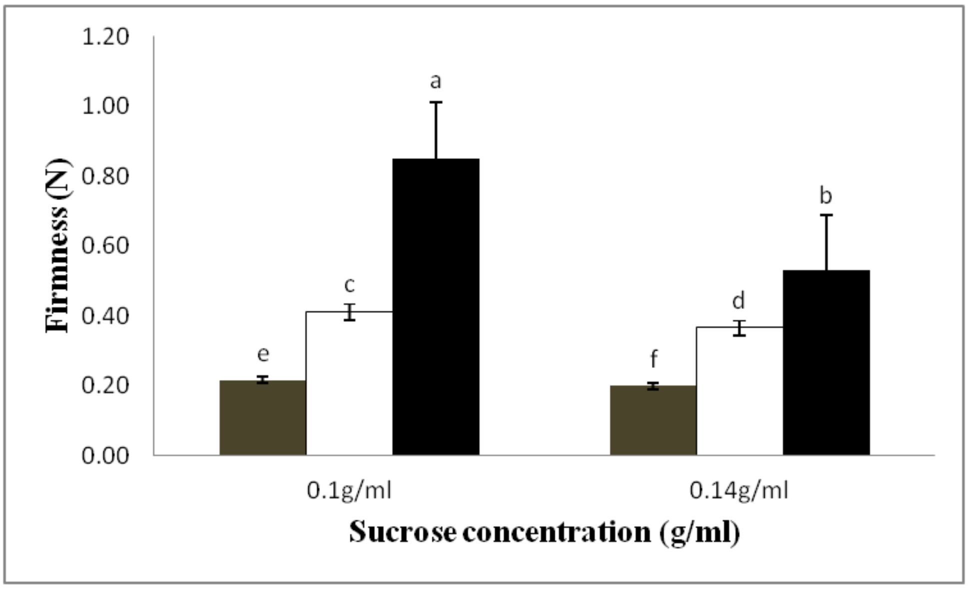



**Figure 2.** Firmness values of lactose free desserts containing different waxy maize and sucrose concentrations (gray-0.032 g/ml, white-0.040 g/ml and black-0.048 g/ml waxy maize starch)

Increase in the textural properties (cohesiveness and firmness) with increase in the sucrose concentration of desserts in amylomaize containing desserts is obviously related to the amylose content of amylomaize starch. In order to understand the effect of sucrose on amylomaize starch, it is essential to understand gelatinization mechanism of high amylose containing starch. It is difficult to explain mechanism of high amylose containing starch due to several factors which make the system complex. Amylomaize starch contains amylose, free amylose, lipid-amylose bindings and amylopectin molecules. It is mandatory to explain the effect of sucrose on these components separately to get better insight in to the mechanism. Keetels et al. (1995) have stated that during heating, amylose molecules leach out of swollen granules because of the inconsistency of amylopectin and amylose molecules (Chiotelli et. al., 2000). In addition, amylose molecules have higher mobility than amylopectin molecules due to its structure and molecular weight. Also gelation of amylose is faster than amylopectin (Chiotelli et al., 2000). Kibar et. al., (2009) proposed in their study that gelatinization degree based on the absorption peak can be taken as the ratio of solubilized amylose to the total amylose in the starch. In other words, rather than the amount of total amylose, solubilized amylose controls the gelatinization. In addition, Kibar et al., (2009) concluded that solubilization of high amylose containing starch controlled the gelatinization process. Solubility of amylose depends on several factors such as water diffusion, size and amount of pores in the granule. Gonera and Cornillon (2002) have observed in their study that sucrose entered starch granules and brought some water with itself. Entering of sucrose has increased rate of swelling of granules which helps amylose to leach out and have enlarged pores which amylose can exude easily. Increasing solvent effect of sucrose has been mentioned by several researchers such as Spies and Hoseney (1982), Kim and Walker (1992). In conclusion, addition of sucrose resulted in faster and efficient amylose leaching. Secondly, amylomaize has amylose-lipid bonds which form crystals and intervene in diffusion of water. Melting of these crystals occur between 104 and 125 $^{0}$C. Cooking temperatures of desserts were lower than these temperatures. Thus temperature can't be the factor affecting lipid-amylose bonds. It is a well known fact that sucrose forms bonds with starch molecules, those bonds may break lipid-amylose bonds leaving amylose free and increasing the amount of solubilized amylose content which contribute to gel strength.

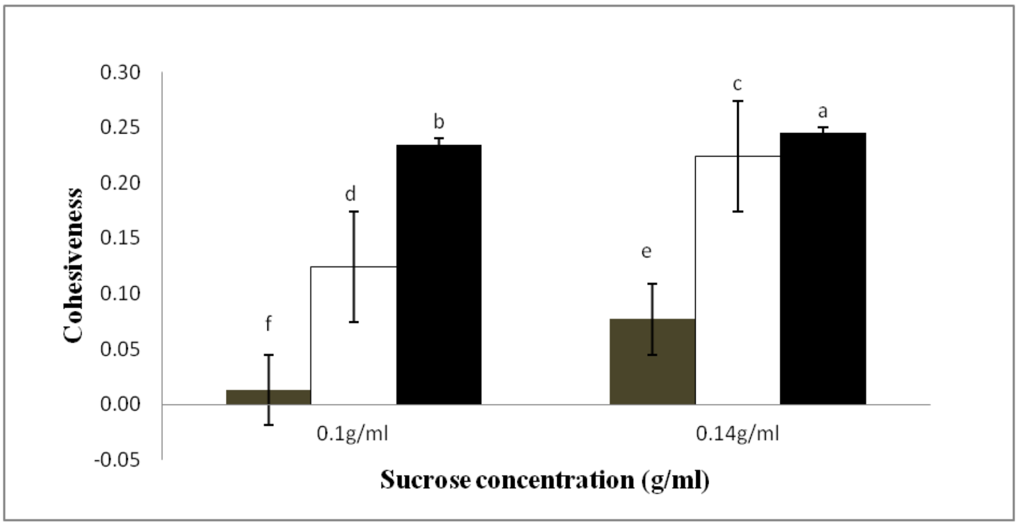



**Figure 3.** Cohesiveness values of lactose free desserts containing different amylomaize and sucrose concentrations (gray-0.064 g/ml, white-0.072 g/ml and black-0.080 g/ml amylomaize starch)

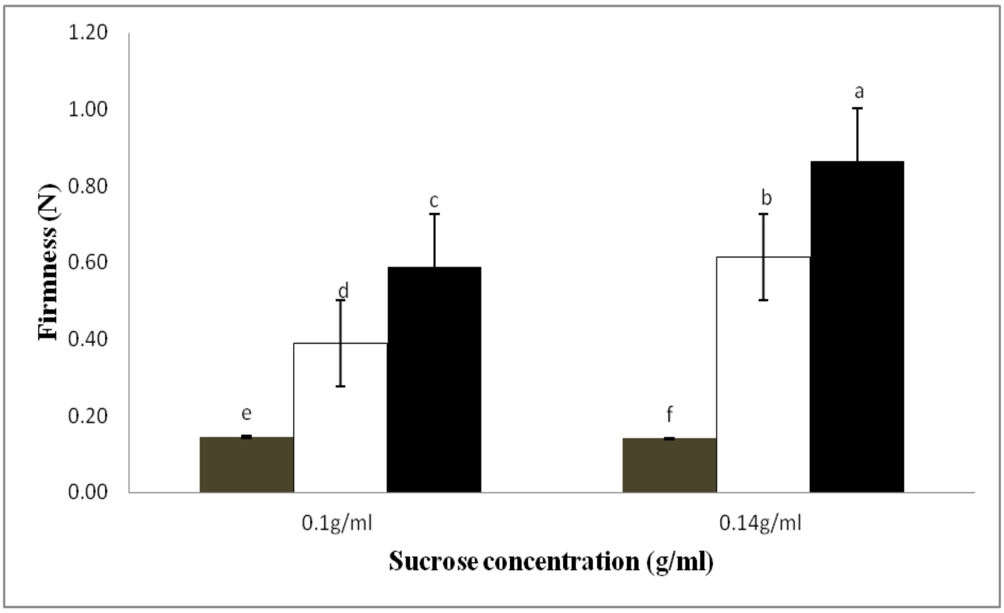



**Figure 4.** Firmness values of lactose free desserts containing different amylomaize and sucrose concentrations (gray-0.064 g/ml, white-0.072 g/ml and black-0.080 g/ml amylomaize starch)

### 3.2.2 Effect of gums on texture of dairy desserts

In general, increasing gum concentrations increased cohesiveness and firmness of dairy desserts as expected (Figures 5-16). Increasing gum concentrations led to the formation of more bonds between starch and gum thus leading more branched structure and stronger gel. Also, Anova analysis shows that there is significant difference in the texture of desserts containing different gum concentrations (Table A.5-A.16).

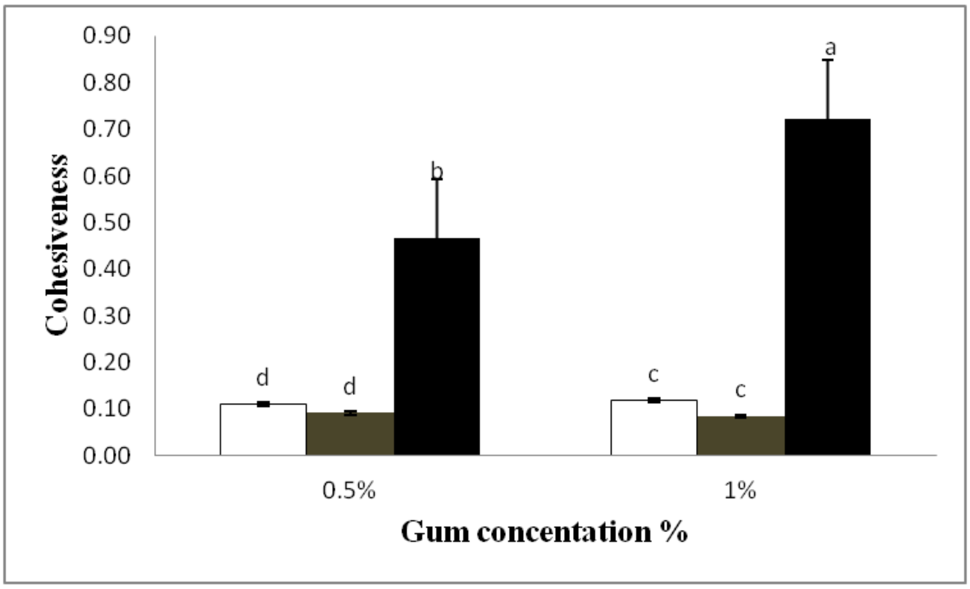



**Figure 5.** Cohesiveness values of lactose free desserts containing 0.032 g/ml waxy maize and different gum types at different concentrations (white-guar, gray-arabic and black-κ-carrageenan)

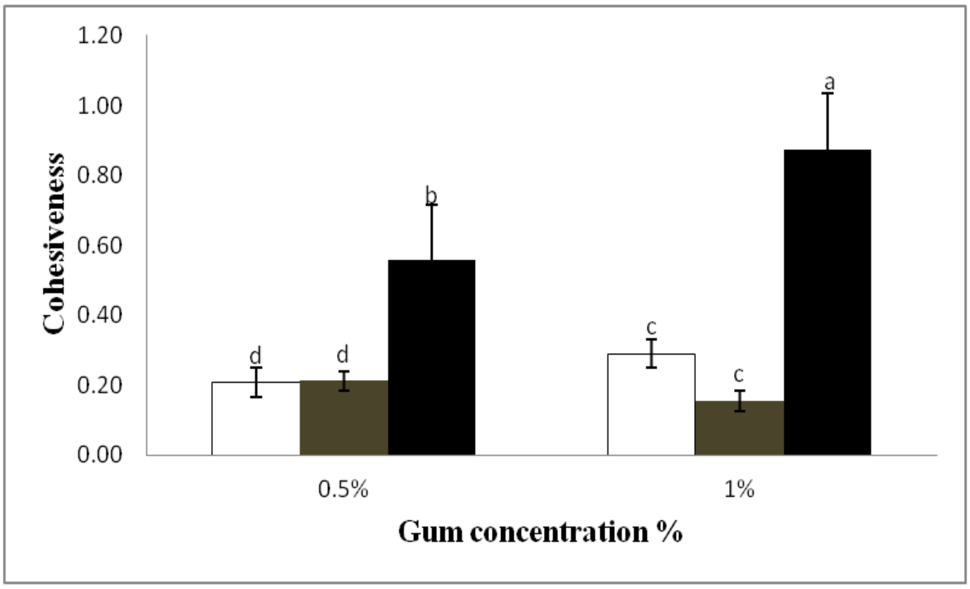



**Figure 6.** Cohesiveness values of lactose free desserts containing 0.040g/ml waxy maize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

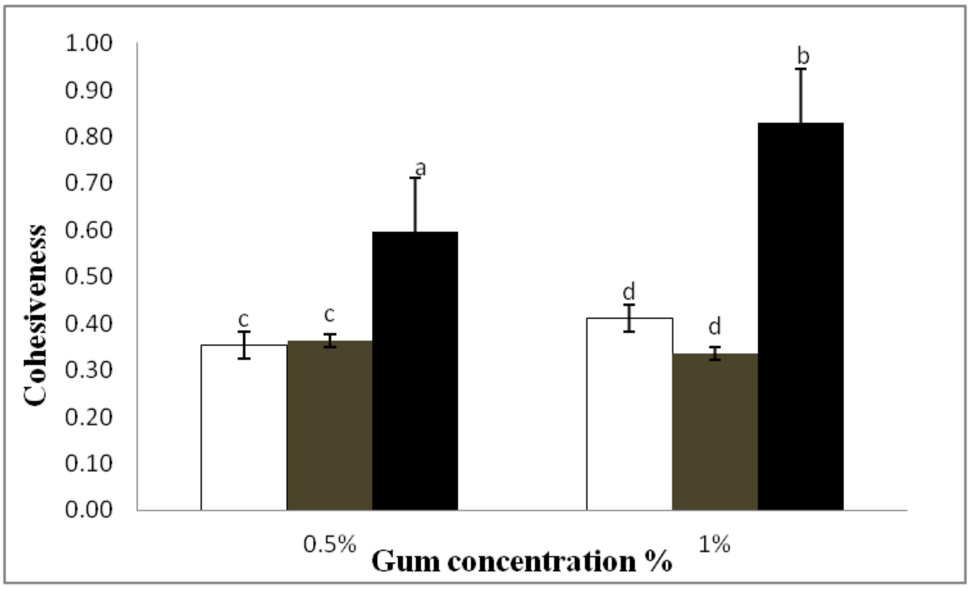



**Figure 7.** Cohesiveness values of lactose free desserts containing 0.048 g/ml waxy maize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

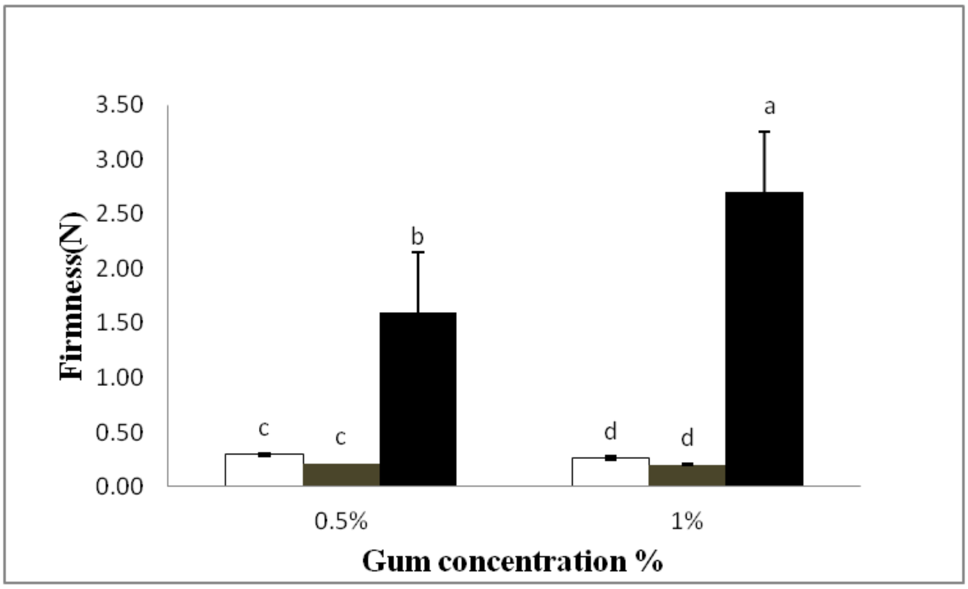



**Figure 8.** Firmness values of lactose free desserts containing 0.032 g/ml waxy maize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

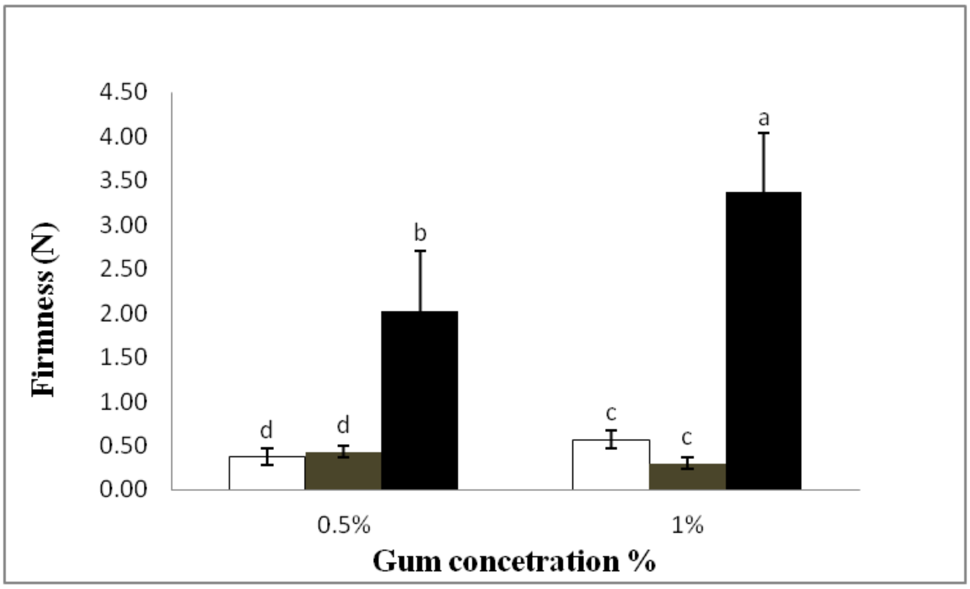



**Figure 9.** Firmness values of lactose free desserts containing 0.040 g/ml waxy maize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

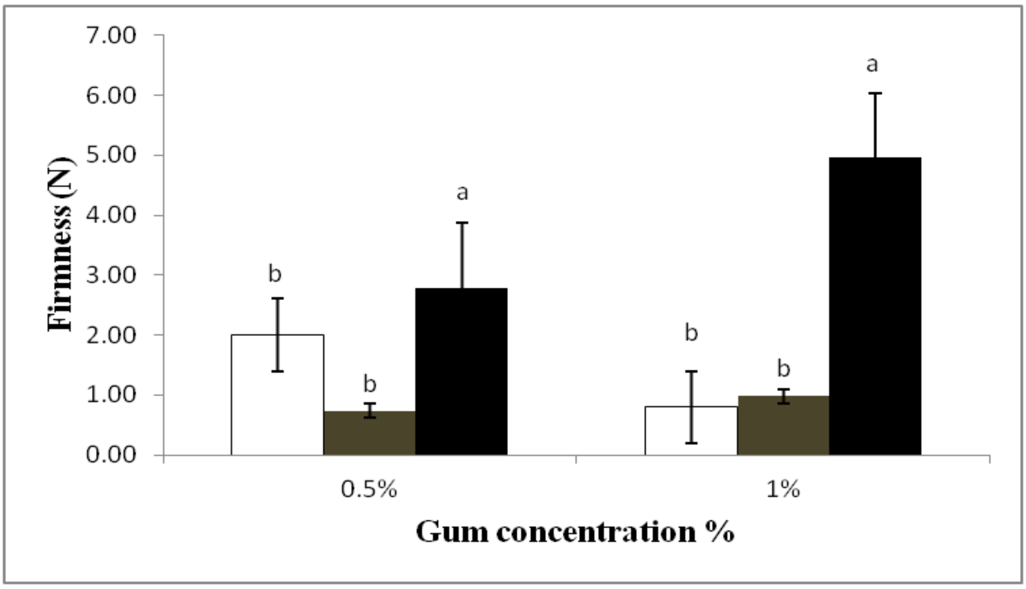



**Figure 10.** Firmness values of lactose free desserts containing 0.048 g/ml waxy maize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

Tester and Sommerville (2003) have investigated the effects of gums on the starch gelatinization, water absorption and enzymatic hydrolysis. They have observed less mobilization of water molecules which prevented gelatinization and this was attributed to the water binding capacity of gums.

According to the Anova analysis gum arabic and guar gum containing desserts, except cohesiveness values of 0.064 g/ml amylomaize containing dessert, don't have significant difference in their textural properties. However, κ-carrageenan affected textural properties of desserts significantly (Table A.5-A.16). Textural properties of κ -carrageenan containing desserts were higher than those of guar and arabic gum containing desserts. This phenomenon can be explained by the interaction of κ-carrageen with milk proteins. Carrageenan interaction with casein micelles occur through electrostatic interaction between positively charged region of κ-casein and negatively charged region of κ-carrageenan (Verbeken et.al, 2006). Strong intermolecular connections improve textural properties. Since, as the intermolecular connections get stronger it will be difficult to break those bonds and penetrate into dessert. In addition, in the presence of starch, carrageenan gelation is believed to be accompanied by the exclusion effect of swollen starch molecules concentrating carrageenan in the continuous water phase (Verbeken et. al., 2006). This adds another additional concentrating effect to the κ-carrageenan.

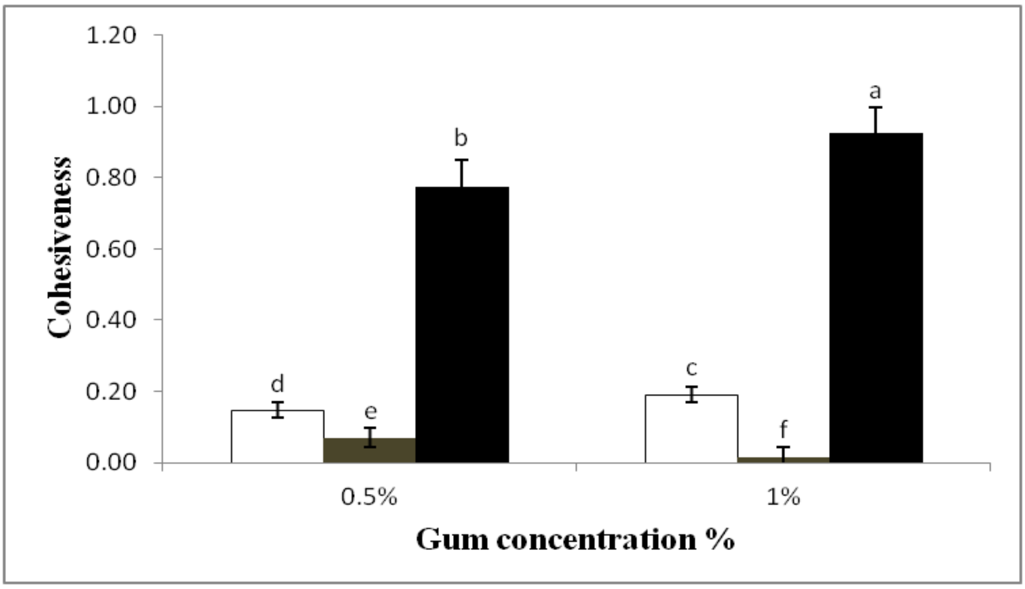



**Figure 11.** Cohesiveness values of lactose free desserts containing 0.064 g/ml amylomaize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

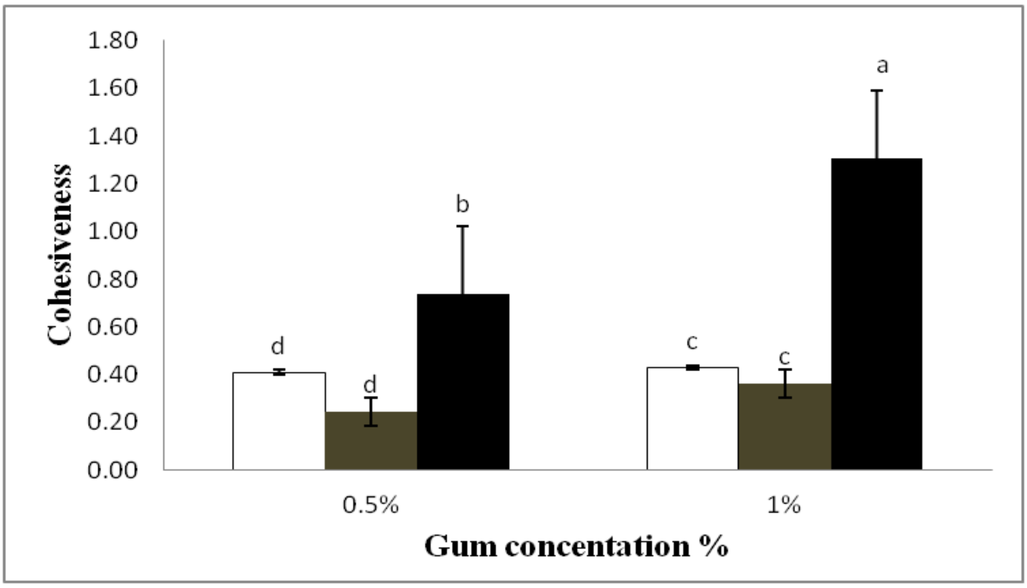



**Figure 12.** Cohesiveness values of lactose free desserts containing 0.072 g/ml amylomaize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

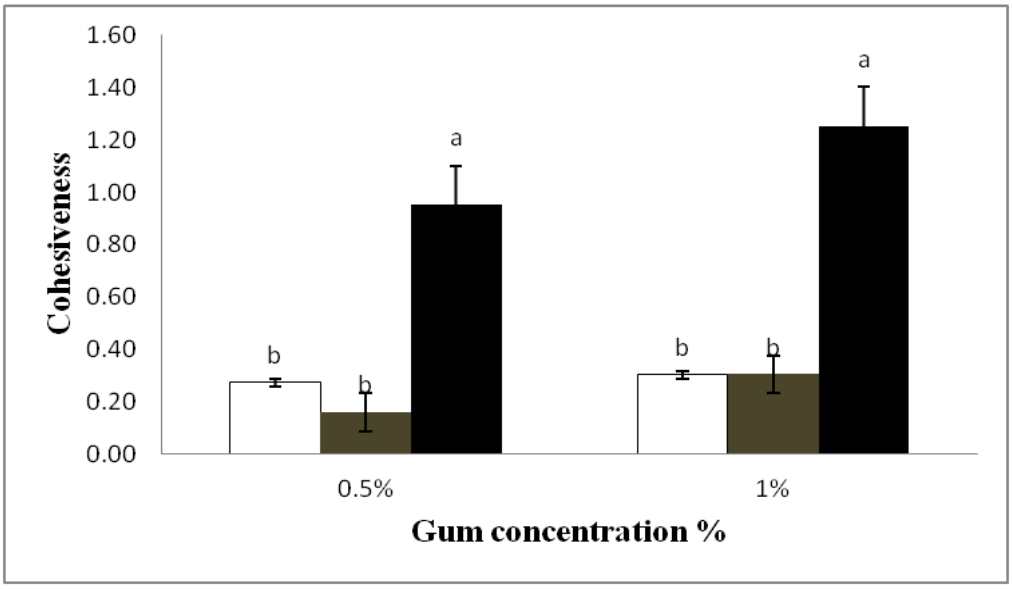



**Figure 13.** Cohesiveness values of lactose free desserts containing 0.080 g/ml amylomaize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

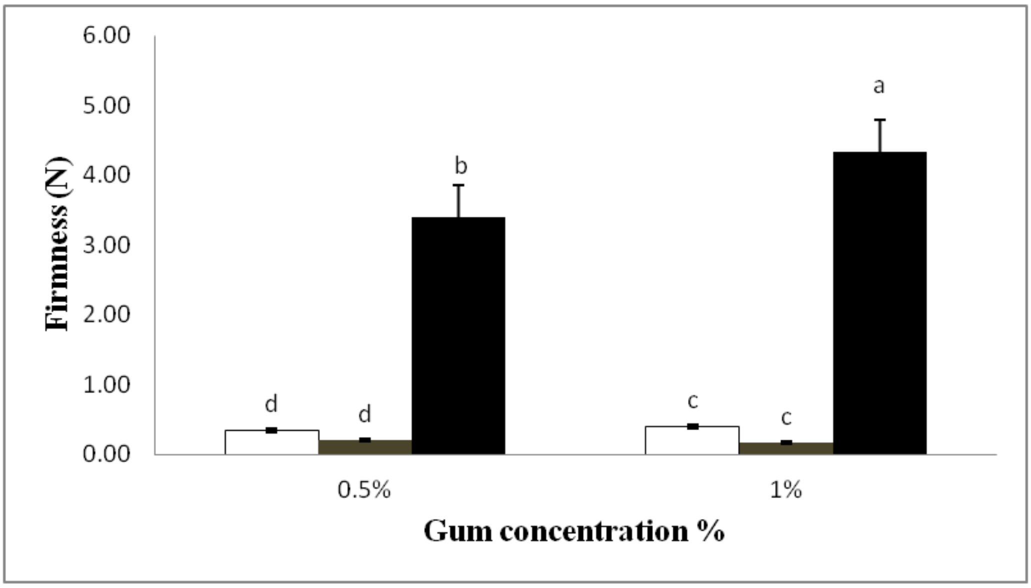



**Figure 14.** Firmness values of lactose free desserts containing 0.064 g/ml amylomaize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

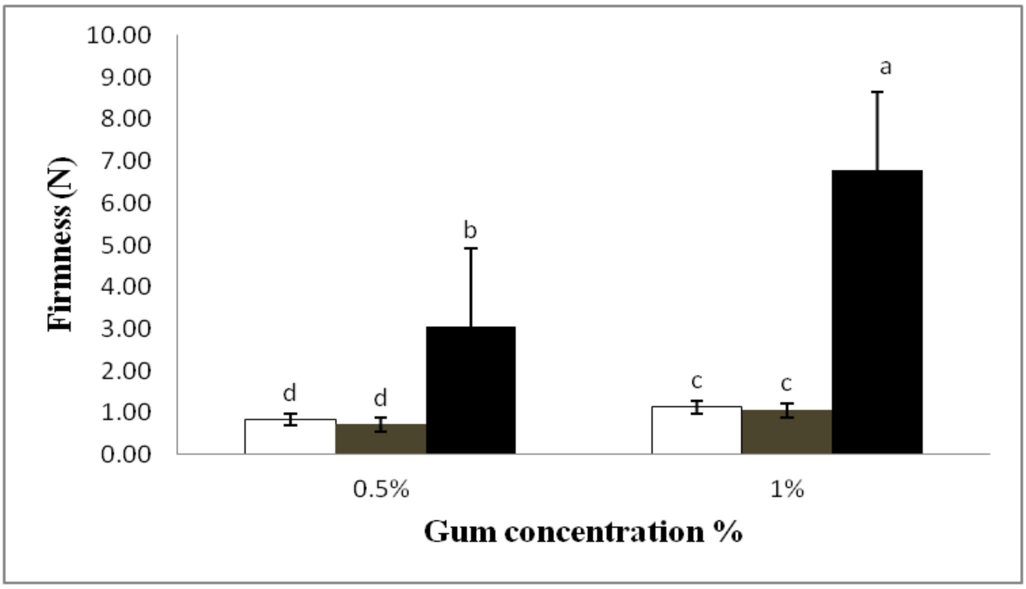



**Figure 15.** Firmness values of lactose free desserts containing 0.072 g/ml amylomaize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

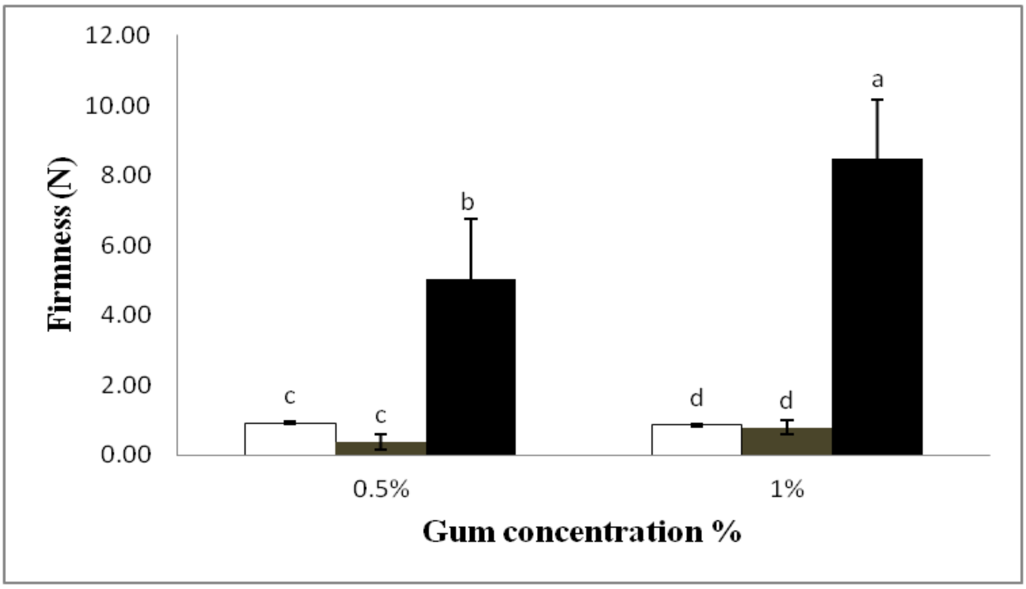



**Figure 16.** Firmness values of lactose free desserts containing 0.080 g/ml amylomaize and different gum types at different concentrations (white-guar, gray-gum arabic and black-κ-carrageenan)

### 3.2.3 Comparison of lactose free and lactose containing desserts in terms of texture

When waxy maize starch and the same concentration of sucrose (0.14 g/ml) were used, textural properties of lactose containing and lactose free desserts were similar (Table 3). In amylomaize containing desserts, lactose containing desserts have lower textural properties than lactose free desserts that contain the same amount of sucrose (0.14g/ml) (Table 3). This is due to the difference in the milk sugars, lactose and glucose and galactose. Lactose is a disaccharide and it is known that disaccharides intervene in gelation of starch more than monosaccharides (Kim and Walker 1992). In addition, glucose has chain reorganization promoting effect during retrogradation (Propokowich and Biliaderis 1995). This effect of glucose helps to form more organized chains which contribute to texture.

**Table 3**. Textural properties of lactose free and lactose containing desserts with 0.14 g/ml sucrose.

| Starch concentration | Milk type | Cohesiveness | Firmness (N) |
|---|---|---|---|
| 0.032 g/ml waxymaize | LC [a] | 0.0807 | 0.2113 |
| | LF [b] | 0.0710 | 0.1984 |
| 0.040 g/ml waxymaize | LC | 0.1886 | 0.3829 |
| | LF | 0.1823 | 0.3655 |
| 0.048 g/ml waxymaize | LC | 0.3045 | 0.6438 |
| | LF | 0.2901 | 0.5288 |
| 0.064 g/ml amylomaize | LC | 0.0126 | 0.1495 |
| | LF | 0.0769 | 0.1400 |
| 0.072 g/ml amylomaize | LC | 0.0841 | 0.2526 |
| | LF | 0.2238 | 0.6137 |
| 0.080 g/ml amylomaize | LC | 0.0448 | 0.1784 |
| | LF | 0.2449 | 0.8635 |

[a]Lactose containing milk

[b]Lactose free milk

### 3.3 Rheological properties of dairy desserts

Rheology of dairy desserts is very important since flow properties define the structure of dessert during production and it is important from textural, sensorial and convenience aspects point of view such as stability, scooping, aroma release, filling (Fischer and Windhab, 2011). The rheology of food depends on the fat content, type and concentration of starch, sugar and hydrocolloids (Tarrega and Costel (a), 2006). For the rheological analysis, desserts that contain 0.5 % gum concentration were chosen. Because 1% gum concentration containing desserts were too firm and solid like to be considered as dessert and also it is much more economical to use less gum concentration. In addition, only desserts containing waxy maize starch were analyzed since concentration of waxy maize starch required to develop the structure was lower than that of amylomaize starch.

#### 3.3.1 Steady Shear properties

Figures 17 and 18 are the sample graphs showing flow behavior of different dessert formulations. Shear rate versus shear stress data at $25^0$C were fitted successfully to Power Law model ($\tau$=K*$(\gamma)^n$). All of the samples showed non Newtonian, shear thinning, pseudoplastic behavior with the low n values (Table 4-6). This type of flow occurs when hydrodynamic forces break the structural units during shearing (Dogan et. al., 2011). In other words, as the shear applied to the liquid increases, the viscosity decreases because of broken down connective bonds between components of the system (Demirkesen et. al., 2010). Range of n values is between 0.43 and 0.23. This shows that apparent viscosity of desserts decreased as the shear rate increased. Dickinson and Stainsby (1982) have related this shear thinning behavior of desserts to interaction of partially broken down casein micelles at the droplet surface of desserts. Our findings are in agreement with other studies (Gonzalez and Costel, 2006; Tarrega and Costel (b), 2006, 2007; Doublier and Durand, 2008; Toker et. al., 2012).

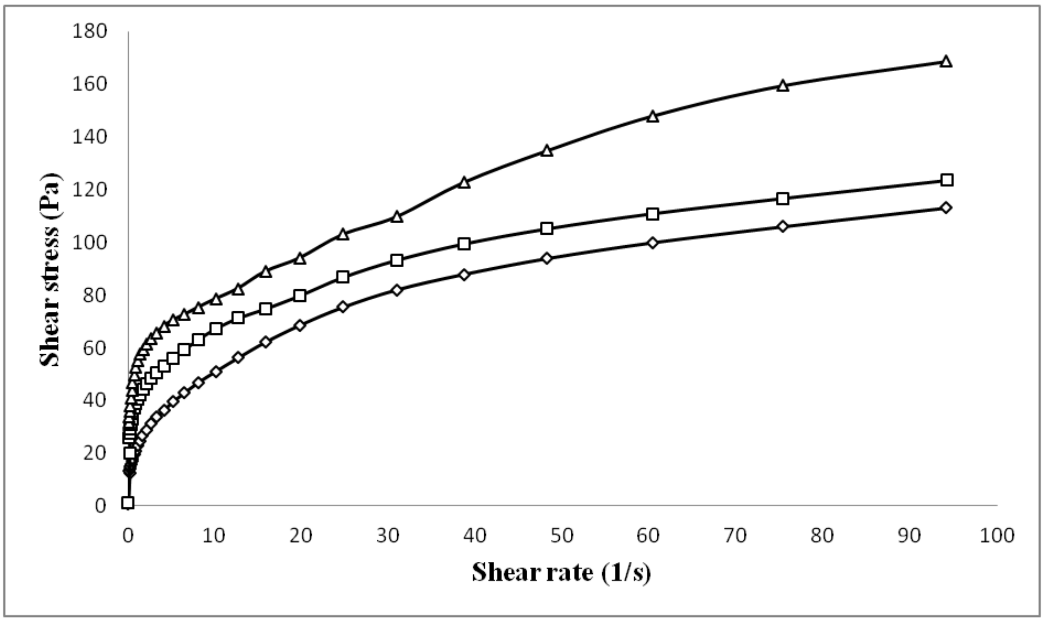



**Figure 17**. Shear stress versus shear rate graph of 0.040 g/ml waxy maize starch containing lactose free desserts that contain 0.5% Guar (◊), 0.5% arabic gum (□) and 0.5% κ-carrageenan (Δ)

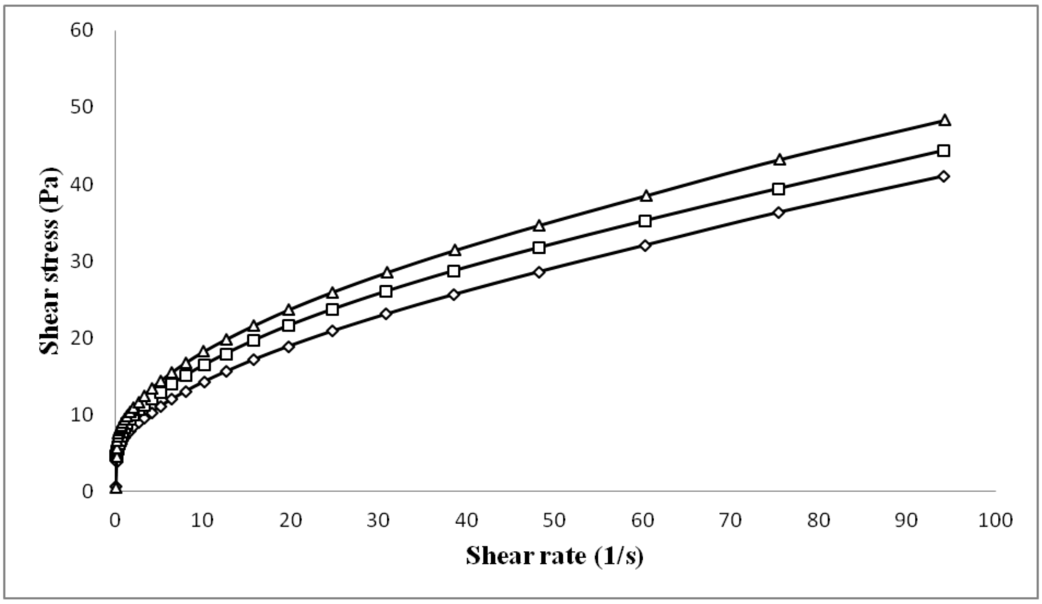



**Figure 18**. Shear stress versus shear rate graph of 0.032 g/ml waxy maize starch containing dessert formulations; lactose containing with 0.14 g/ml sucrose (◊), lactose free with 0.10 g/ml sucrose (□) and lactose free desserts with 0.14 g/ml sucrose (Δ)

Increasing starch concentration in gum free desserts increased consistency index (K) of desserts (Table 4-6). This is in good agreement with the study of Tarrega and Costel (b) (2006). Desserts containing κ-carrageenan had lower n but higher K value than guar gum containing ones (Table 4-6). This is in agreement with the study of Toker et. al., (2013). This may be explained by the special electrostatic interaction of κ-carrageen molecules with casein proteins of milk. These strong electrostatic bonding creates strong bonds. Addition of gums decreased flow index and increased consistency coefficient of desserts. In lactose free desserts, when sucrose concentration was reduced, lower consistency coefficient but higher flow behavior index were observed. When 0.040 g/ml waxy maize starch was used, consistency coefficient of lactose free desserts with different sucrose concentration or with guar gum was close to that of lactose containing dessert.

**Table 4**. Consistency coefficient (K), flow behavior index (n) and $R^2$ values of desserts that contain 0.032g/ml waxy maize starch

| Dessert Formulation | n | K | $R^2$ |
|---|---|---|---|
| LC[a]+0.14g/ml sucrose | 0.38 | 1.87 | 0.91 |
| LF[b]+0.10g/ml sucrose | 0.33 | 2.11 | 0.99 |
| LF+0.14g/ml sucrose | 0.32 | 2.23 | 0.98 |
| LF+0.5% Guar | 0.37 | 2.12 | 0.99 |
| LF+0.5% Gum arabic | 0.26 | 2.67 | 0.94 |
| LF+0.5% κ-carrageenan | 0.32 | 2.48 | 0.97 |

[a]Lactose containing milk

[b]Lactose free milk

**Table 5**. Consistency coefficient (K), flow behavior index (n) and $R^2$ values of desserts that contain 0.040g/ml waxy maize starch

| Dessert Formulation | n | K | $R^2$ |
|---|---|---|---|
| LC[a]+0.14g/ml sucrose | 0.31 | 3.03 | 0.98 |
| LF[b]+0.10g/ml sucrose | 0.37 | 2.94 | 0.99 |
| LF+0.14g/ml sucrose | 0.31 | 3.15 | 0.99 |
| LF+0.5% Guar | 0.43 | 2.98 | 0.89 |
| LF+0.5% Gum arabic | 0.25 | 3.65 | 0.99 |
| LF+0.5% κ-carrageenan | 0.23 | 3.93 | 0.98 |

[a]Lactose containing milk

[b]Lactose free milk

**Table 6.** Consistency coefficient (K), flow behavior index (n) and $R^2$ values of desserts that contain 0.048g/ml waxy maize starch

| Dessert Formulation | n | K | $R^2$ |
|---|---|---|---|
| LC[a]+0.14 g/ml sucrose | 0.28 | 3.70 | 0.96 |
| LF[b]+0.10 g/ml sucrose | 0.43 | 3.13 | 0.87 |
| LF+0.14 g/ml sucrose | 0.30 | 3.66 | 0.91 |
| LF+0.5 % Guar | 0.35 | 3.45 | 0.99 |
| LF+0.5 % Gum arabic | 0.39 | 2.97 | 0.95 |
| LF+0.5 % κ-carrageenan | 0.26 | 3.86 | 0.99 |

[a]Lactose containing milk

[b]Lactose free milk

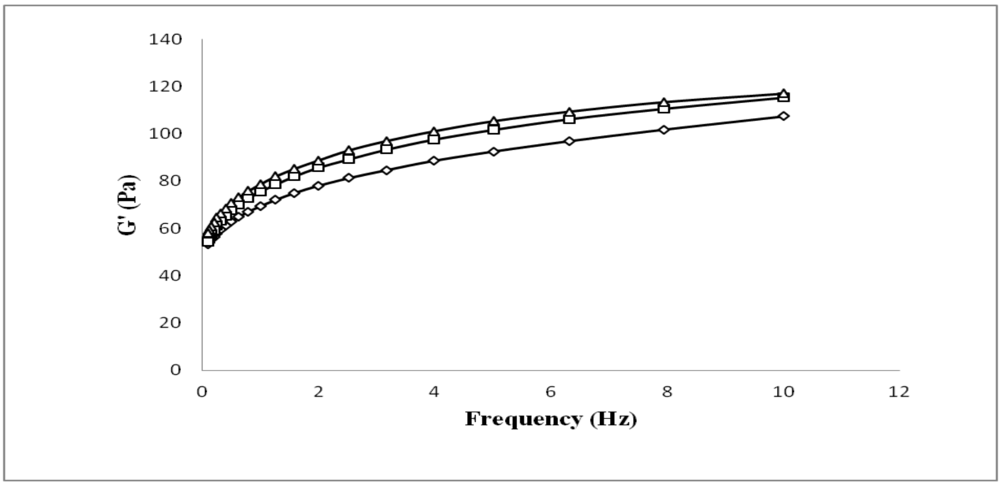
### 3.3.2 Viscoelastic Properties

Mechanical spectra of dairy desserts obtained from sweep tests are given in Figures 19 & 20. As expected, storage modulus (G′) for all dairy desserts were higher than loss modulus (G″) implying that samples had weak-gel like structure (Clark and

Ross-Murphy, 1987; Toker, et. al., 2013). Gonzalez-Thomas et. al., (2008), Tarrega and Costel (a), /b) (2006) have obtained similar results. As frequency of sweep test increased, both loss and storage modulus of dairy desserts increased. This behavior is considered to be typical for weak gel like structures (Nunes et. al., 2006). This also indicates that elastic poperties are greater than viscous properties. Sivaramakrishnan et. al., (2004) has explained this phenomenon with the lack of binding agents in samples which has effect on water absorption.

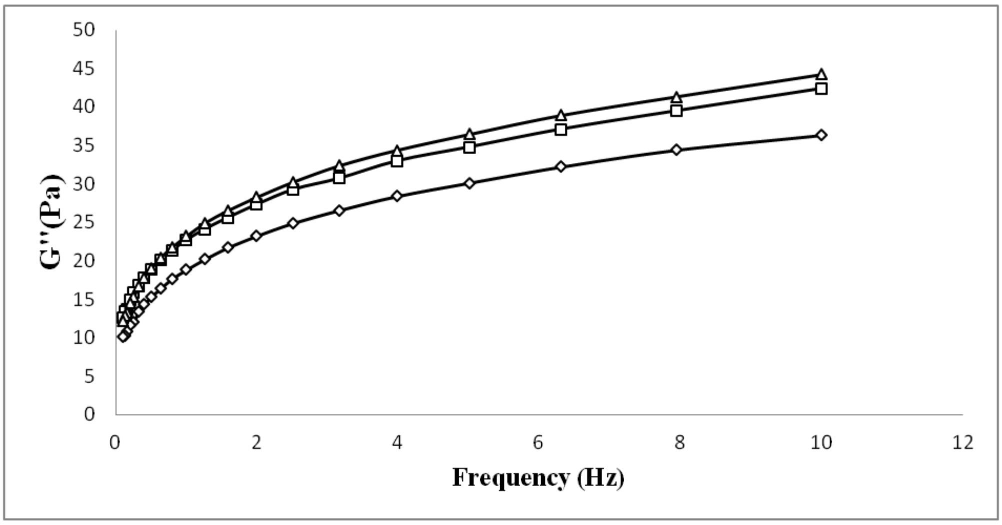
As the starch concentration of desserts increased the storage and loss modulus of desserts increased (Table 7). This is an expected situation, rheological properties of starch are determined by the swelling capacity and rigidity of particles. In suspensions, volume fraction of starch molecules determines the rheological properties. As the concentration of starch increased, volume fraction of starch in desserts increased, resulting in increase in the dynamical properties of desserts.

The storage and loss modulus of lactose free desserts were higher than that of lactose containing desserts (Figure 19 and Table 7). This may be explained by retardation of retrogradation in the presence of lactose. Effect of sucrose on the rheology of starch-sugar-water systems has been extensively studied (Propokowich and Biliadersis, 1995; Chiotelli et.al., 2000; Yang et. al., 2003). Increase in sucrose concentration in lactose free desserts caused increase in the storage and loss modulus of desserts (Table 7). This is probably due to effect of hydrogen bonding (Yang et. al., 2004), since as the number of hydrogen bonding increases, the G' and G'' of desserts increase.



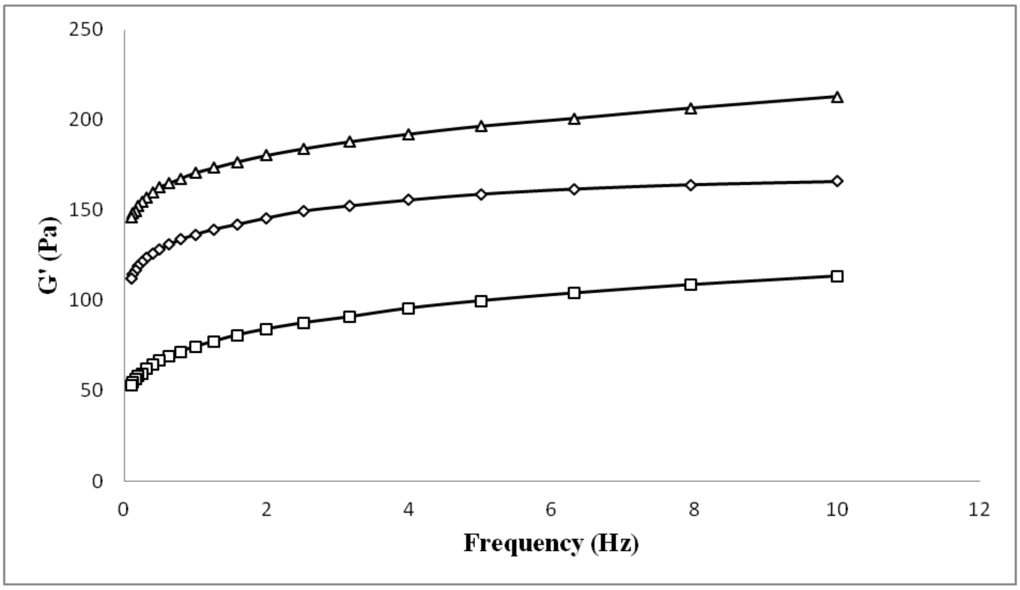

(a)

**Figure 19**. Storage (a) and Loss modulus (b) of different dessert formulations with 0.040g/ml waxy maize starch; lactose containing with 0.14 g/ml sucrose (◊), lactose free with 0.10 g/ml sucrose (□) and lactose free with 0.14 g/ml sucrose (Δ)



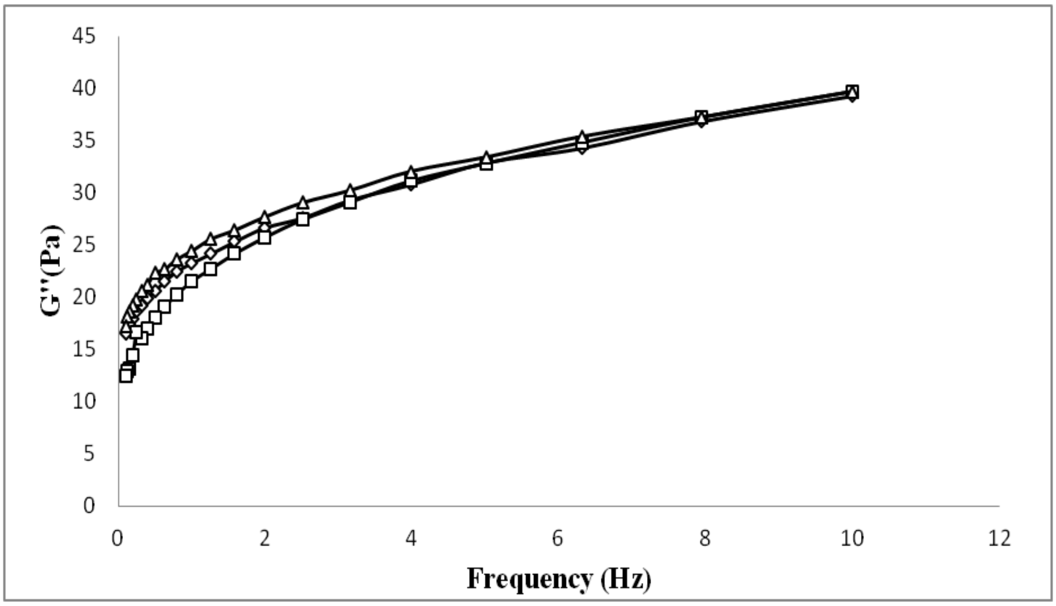

(b)

**Figure 19**. Storage (a) and Loss modulus (b) of different dessert formulations with 0.040g/ml waxy maize starch; lactose containing with 0.14 g/ml sucrose (◊), lactose free with 0.10 g/ml sucrose (□) and lactose free with 0.14 g/ml sucrose (Δ) (continued)




(a)

**Figure 20**. Storage (a) and Loss modulus (b) of different dessert formulations with 0.048 g/ml waxy maize starch; 0.5% guar (◊), 0.5% arabic gum (□) and 0.5% κ-carrageenan (Δ)




(b)

**Figure 20**. Storage (a) and Loss modulus (b) of different dessert formulations with 0.048 g/ml waxy maize starch; 0.5% guar (◊), 0.5% arabic gum (□) and 0.5% κ-carrageenan (Δ) (continued)

Addition of gums to the desserts caused increase in the storage and loss modulus of all desserts (Table 7). This is in agreement with the studies in literature (Tarrega and Costell (a) 2006; Verbeken et. al., 2006; Doublier and Durand, 2008; Gonzalez-Thomas et. al., 2008; Toker et.al., 2013). Gum addition increased G' and G'' due to synergistic effect between gum and starch. Similar conclusions have been reported by several authors (Shi and BeMiller, 2002). Closs et. al., (1999) and Mandala et. al., (2004) have stated that this synergistic effect is due to phase separation, on the other hand Abdulmola et. al., (1996) have explained this phenomenon by intergranular association. Among gums, κ-carrageenan had the greatest effect on the G' and G'' mostly because of two reasons; 1) special interaction with κ-casein molecules and 2) volume fraction of dispersed molecules because of the presence of κ-carrageenan on the dairy dessert system (Tarrega and Costell (a), 2006).

**Table 7**. Storage and loss modulus values of waxy maize starch containing desserts

| Dessert formulation | Starch concentration | | | | | |
|---|---|---|---|---|---|---|
| | 0.032g/ml | | 0.040g/ml | | 0.048g/ml | |
| | G'(Pa) | G"(Pa) | G'(Pa) | G"(Pa) | G'(Pa) | G"(Pa) |
| LC+0.14 g/ml sucrose | 22 | 7 | 73 | 20 | 132 | 32 |
| LF+0.10 g/ml sucrose | 38 | 12 | 79 | 24 | 107 | 28 |
| LF+0.14 g/ml sucrose | 38 | 12 | 82 | 25 | 129 | 32 |
| LF+0.5% Guar | 36 | 14 | 104 | 24 | 138 | 25 |
| LF+0.5%Gum arabic | 47 | 14 | 108 | 24 | 78 | 23 |
| LF+0.5% κ-carrageenan | 45 | 12 | 195 | 28 | 174 | 26 |

### 3.4 NMR Relaxation Time

To better understand the molecular level of gelatinization, spin-spin relaxation times were obtained for the desserts with different formulations. T2 profile of desserts shows that as starch concentration of lactose free desserts that didn't contain gum increased, T2 decreased (Table 8). ANOVA analysis of lactose free desserts was conducted to observe the effect of starch concentration on T2 and it revealed that there was significant difference in the T2 values (Table A.17). This is in agreement with the study of Tananuwong and Reid (2004). In their study, as the waxy maize starch concentration increased, T2 decreased. Due to structural disruption during heating, diffusive water exchange between intra and extra granular regions of water-starch mixture increases, which decreases the mobile water fraction (Tananuwong and Reid, 2004). In other words, as the starch concentration increases, there will be more available regions to make hydrogen bonding and thus leading to less mobile water amount. Choi and Kerr (2003) have concluded in their NMR study of wheat starch gels that as the water content in starch-water solution decreases, T2 decreases. The opposite is also true. When starch concentration of water-starch solution increases, T2 decreases. As the starch amount increases, T2 values of lactose containing desserts increase showing opposite trend with lactose free desserts. This may be due to lactose content of desserts.

**Table 8**. T2 values of lactose containing and lactose free desserts

| | Starch Concentration (g/ml) | | |
|---|---|---|---|
| Dessert Formulations | 0.032 | 0.040 | 0.048 |
| LC+0.14g/ml sucrose | 142.0 | 145.0 | 151.4 |
| LF+0.14g/ml sucrose | 144.4 | 134.1 | 127.0 |
| LF+0.10g/ml sucrose | 145.0 | 135.0 | 124.4 |

Lactose free desserts that have different sucrose concentration (0.10 g/ml and 0.14g/ml) have almost the same T2 value (Table 8). Also statistical analysis shows that there is no significant difference between T2 of these desserts having different sucrose content (Table A.17). However, it would be logical to expect increase in the T2 value when higher amount of sucrose was used in lactose free desserts. Chinachoti and Stengle (1990) have found that addition of sucrose to starch-water solution increased T2 value. Moreover, simply by looking textural properties, one would say that T2 of high sucrose containing dessert should be higher because cohesiveness of high sucrose containing dessert was lower when waxy maize was used. Cohesiveness of dairy desserts are attributed to the water binding capacity (Vidigal et.al., 2012). Then, if T2 values of lactose free desserts, which reveal bound water, don't have significant difference, cohesiveness of desserts should have no significant difference too. On the other hand, Propokowich and Biliaders (1994) have concluded that amylopectin is sensitive to sucrose addition. Chinachoti and Stengle (1990) have proposed that added sucrose caused release of water tightly bound starch. That is why texture decreased as sucrose concentration increased. Then, why didn't increase in sucrose result in increase the T2 value of high sucrose containing dessert. Mora-Gutierrez and Baianu (1989) have studied this phenomenon extensively and concluded that there is no correlation between viscosity and mobile water. They have suggested that water in the gel state of amylopectin could be trapped between hydrogen bonded, structured domains. So even if water is not bound to starch, it may not be seen in the NMR analysis. That is why even if water is free it may be seen immobile in NMR analysis.

Two-way ANOVA showed that both starch concentration and gum type have significant effect on T2 (Table A.17). There was also a significant interaction between starch concentration and gum type. This shows that there is a competition to bind water in the medium. ANOVA analysis of lactose free desserts and lactose free desserts that contain gums reveal that there is no significant difference in T2 values with some exceptions (Figure 21, Table A.17). On the other hand, textural properties of gum containing desserts are higher than those of lactose free desserts that have no gum. This shows that gums contribute to body formation by interacting with starch and milk proteins rather than binding water.

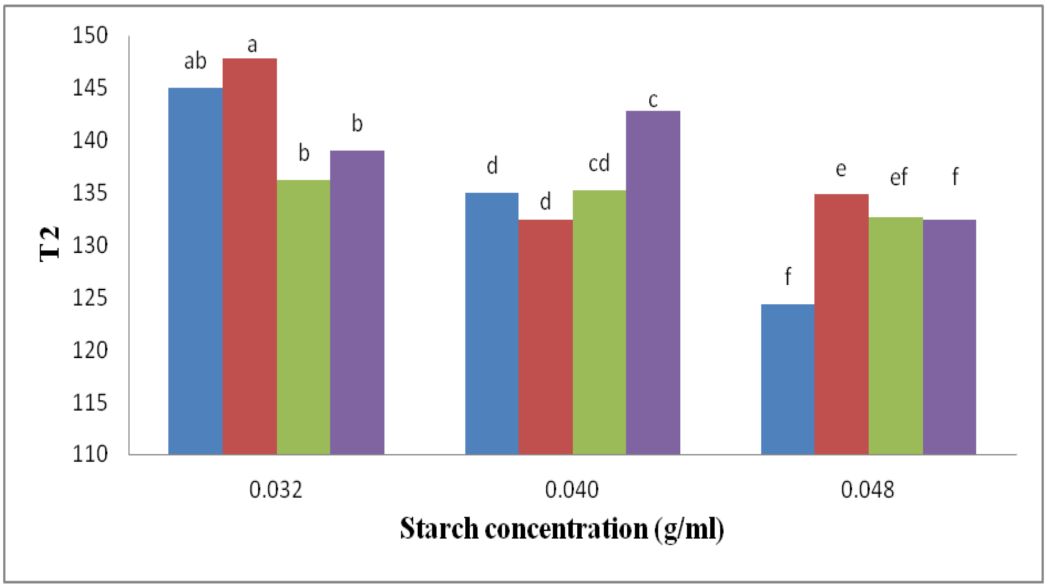



**Figure 21**. T2 values of lactose free and gum containing desserts. Blue color- lactose free desserts, red color-0.5% guar gum containing lactose free dessert, green color-0.5% arabic gum containing dessert and violet color-0.5% κ-carrageenan containing dessert.

## 3.5 Sensory analysis

It is a known fact that texture and rheology are an important factor effecting products' acceptability by consumers. Lactose containing dessert and lactose free dessert formulations having similar textural and rheological properties with the lactose containing one were chosen for sensory analysis. Figures 22 and 23 show the sensory evaluation of different desserts (Table A.18-19). Taste of lactose free dessert that contains 0.14g/ml sugar was less liked one, panelists found it too sweet. If lactose is converted to glucose and galactose, milk tastes sweeter. There was no significant difference between lactose free (with reduced sugar level) and lactose containing desserts in terms of taste.

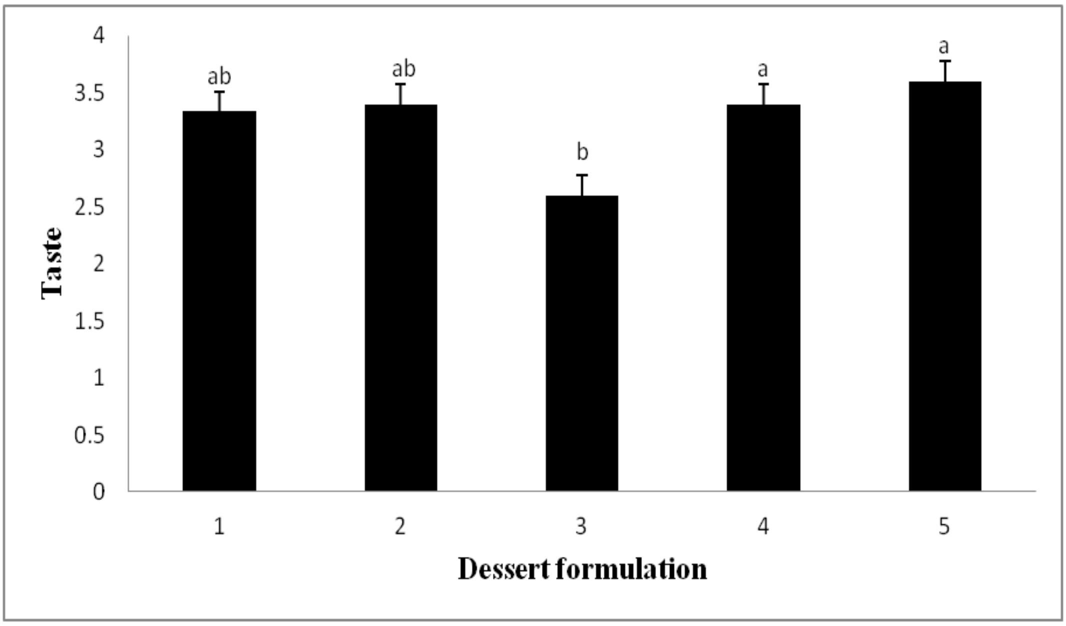



**Figure 22**. Acceptability of desserts in terms of taste

| | |
|---|---|
| 1 | lactose containing dessert with 0.14 g/ml sucrose (control dessert) |
| 2 | 0.040g/ml starch+0.10 g/ml sucrose containing lactose free dessert |
| 3 | 0.040 g/ml starch+0.14 g/ml sucrose containing lactose free dessert |
| 4 | 0.040g/ml starch+κ-carrageenan containing lactose free dessert |
| 5 | 0.032g/ml starch+κ-carrageenan containing lactose free dessert |

Texture of lactose free dessert that contained 0.10 g/ml sucrose was the most liked one (Figure 23). Statistical analysis shows that 0.032g/ml waxy maize + κ-carrageenan containing desserts did not have significant difference with control dessert. Panelists found 0.032g/ml waxy maize + κ-carrageenan containing dessert less creamy compared to lactose free and lactose containing desserts. In dairy desserts, creaminess is a significant factor since it affects acceptability of product from consumers (Elmore et. al, 1999). This can be attributed to the carrageenan. Addition of κ-carrageenan to desserts decreased the creamy sensation of desserts by forming firmer texture. Tarrega and Costell (a), (2006) have stated in their study that creaminess is factor of both texture and taste/flavor attributes. Panelists stated that since 0.032g/ml waxy maize + κ-carrageenan was firmer they felt creamy sensation less. In addition, Weenen et. a.l, (2005), have found that when it was used noseclips during sensory analysis creaminess of desserts decreased which implies the positive effect of the flavor to creamy perception (Tarrega and Costell (b), 2006). Tarrega and Costell (b), (2006) also states that weak gel like sturtures have stronger flavor and sweetnes. However, κ-carrageenan made more solid like structure compared to other desserts without κ-carrageenan. By decreasing κ–carrageenan concentration, this feature can be fixed and get better texture and creamy sensation. In addition, 0.032g/ml waxy maize + κ-carrageenan used dessert was also liked from taste point of view (Figure 22). This situation despite of creaminess decreasing effect of κ-carrageenan may be explained by the positive contribution of sucrose and κ-carrageenan interaction to the sensory properties (Specter and Setser, 1994). Finally, it is handy to use κ-carrageenan because of some positive contributions to dessert such as, it will reduce calorie of dessert by decreasing starch amount and it will increase taste of dessert.

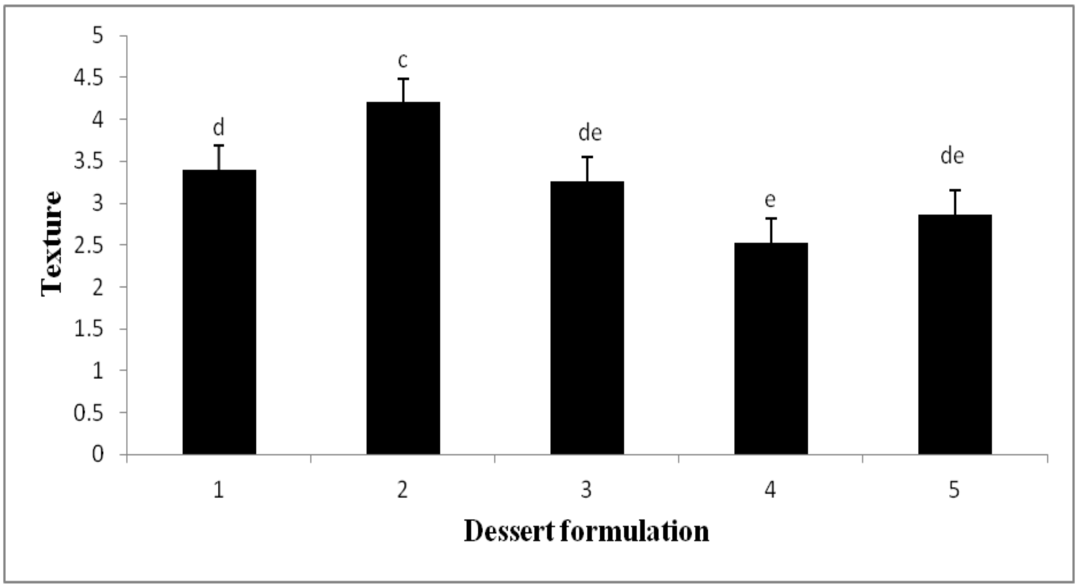



**Figure 23.** Acceptability of desserts in terms of texture

1 lactose containing dessert with 0.14 g/ml sucrose (control dessert)

2 0.040g/ml starch+0.10 g/ml sucrose containing lactose free dessert

3 0.040 g/ml starch+0.14 g/ml sucrose containing lactose free dessert

4 0.040g/ml starch+κ-carrageenan containing lactose free dessert

5 0.032g/ml starch+κ-carrageenan containing lactose free dessert

# CHAPTER 4

# CONCLUSION AND RECOMMENDATIONS

Lactose free desserts were successfully developed by different formulations. It is handful to use waxy maize since concentration of waxy maize was less than that of amylomaize that results in dietic product with low calorie.

Increasing sucrose concentration led to decrease of textural properties of waxy maize containing desserts, on the other hand, it led to increase of textural properties of amylomaize containing desserts. In waxy maize containing desserts, texture was not affected from the presence of lactose. However, when amylomaize was used, texture of lactose containing desserts was lower. When the same amount of sucrose was added to lactose free and lactose containing desserts, panelists found lactose free desserts too sugary. Lactose free desserts with lower sugar concentration were the most acceptable desserts in terms of texture and taste. Usage of waxy maize provided better quality parameters as compared to amylomaize in dairy desserts.

Among gum types κ-carrageenan was the most effective one in body formation, followed by guar gum and arabic gum. Increasing starch or gum concentrations led to the increase in the textural properties of desserts. κ-carrageenan may be used in desserts since it decreases the concentration of starch thus lowering calorie and improving taste of desserts. Taste of κ-carrageenan containing desserts was not significantly different than the desserts containing no gum. However, panelists found κ-carrageenan containing desserts too hard for dairy desserts. By decreasing concentration of κ-carrageenan and waxy maize, better quality lactose free dessert with lower calorie, lower cost and better taste may be obtained

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# APPENDIX A

## ANOVA & DUNCAN TEST TABLES

**Table A.1** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing different concentration sucrose and waxy maize starch concentrations

**Samples:** X1- 1 (0.032g/ml waxy maize), 2 (0.040g/ml waxy maize) and 3 (0.048g/ml waxy maize) X2- 1 (0.10g/ml sucrose) and 2 (0.14g/ml sucrose)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 0.47119967 | 0.15706656 | 143.92 | <.0001 |
| Error | 33 | 0.03601511 | 0.00109137 | | |
| Corrected Total | 36 | 0.50721478 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.928994 | -15.02183 | 0.033036 | -0.219919 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 0.44751905 | 0.22375953 | 205.03 | <.0001 |
| X2 | 1 | 0.02368061 | 0.02368061 | 21.70 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 0.43128035 | 0.21564017 | 197.59 | <.0001 |
| X2 | 1 | 0.02368061 | 0.02368061 | 21.70 | <.0001 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 33 |
| Error Mean Square | 0.001091 |
| Harmonic Mean of Cell Sizes | 12.21145 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .02720 | .02859 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.08942 | 12 | 1 |
| B | 0.19663 | 11 | 2 |
| C | 0.35008 | 14 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 33 |
| Error Mean Square | 0.001091 |
| Harmonic Mean of Cell Sizes | 18.48649 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .02211 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | -0.18617 | 18 | 2 |
| B | -0.25189 | 19 | 1 |

**Table A.2** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing different concentration sucrose and waxy maize starch concentrations

**Samples:** X1- 1 (0.032g/ml waxy maize), 2 (0.040g/ml waxy maize) and 3 (0.048g/ml waxy maize) X2- 1 (0.10g/ml sucrose) and 2 (0.14g/ml sucrose)

SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 2.07857108 | 0.69285703 | 100.71 | <.0001 |
| Error | 34 | 0.23390125 | 0.00687945 | | |
| Corrected Total | 37 | 2.31247233 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.898852 | 17.92198 | 0.082942 | 0.46279 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.90436394 | 0.95218197 | 138.41 | <.0001 |
| X2 | 1 | 0.17420714 | 0.17420714 | 25.32 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.85546590 | 0.92773295 | 134.86 | <.0001 |
| X2 | 1 | 0.17420714 | 0.17420714 | 25.32 | <.0001 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 34 |
| Error Mean Square | 0.006879 |
| Harmonic Mean of Cell Sizes | 12.45283 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .06755 | .07101 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.72672 | 15 | 3 |
| B | 0.38259 | 11 | 2 |
| C | 0.20642 | 12 | 1 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 34 |
| Error Mean Square | 0.006879 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .05469 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.53942 | 19 | 1 |
| B | 0.38617 | 19 | 2 |

**Table A.3** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts different concentration sucrose and amylomaize starch concentations

**Samples:** X1- 1 (0.064g/ml amylomaize), 2 (0.072g/ml amylomaize) and 3 (0.080g/ml amylomaize) X2- 1 (0.10g/ml sucrose) and 2 (0.14g/ml sucrose)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 0.35978896 | 0.11992965 | 21.46 | <.0001 |
| Error | 32 | 0.17883972 | 0.00558874 | | |
| Corrected Total | 35 | 0.53862868 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.667972 | -47.11054 | 0.074758 | -0.158686 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 0.29900206 | 0.14950103 | 26.75 | <.0001 |
| X2 | 1 | 0.06078690 | 0.06078690 | 10.88 | 0.0024 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 0.29900206 | 0.14950103 | 26.75 | <.0001 |
| X2 | 1 | 0.06078690 | 0.06078690 | 10.88 | 0.0024 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 32 |
| Error Mean Square | 0.005589 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .06217 | .06534 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.04256 | 12 | 1 |
| B | 0.16833 | 12 | 2 |
| C | 0.26517 | 12 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 32 |
| Error Mean Square | 0.005589 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .05076 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.11759 | 18 | 1 |
| B | 0.19978 | 18 | 2 |

**Table A.4** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing different concentration sucrose and amylomaize starch concentrations desserts

**Samples:** X1- 1 (0.064g/ml amylomaize), 2 (0.072g/ml amylomaize) and 3 (0.080g/ml amylomaize) X2- 1 (0.10g/ml sucrose) and 2 (0.14g/ml sucrose)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 2.03885367 | 0.67961789 | 14.43 | <.0001 |
| Error | 32 | 1.50717201 | 0.04709913 | | |
| Corrected Total | 35 | 3.54602568 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.574969 | 45.00510 | 0.217023 | 0.482219 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.68876450 | 0.84438225 | 17.93 | <.0001 |
| X2 | 1 | 0.35008917 | 0.35008917 | 7.43 | 0.0103 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.68876450 | 0.84438225 | 17.93 | <.0001 |
| X2 | 1 | 0.35008917 | 0.35008917 | 7.43 | 0.0103 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 32 |
| Error Mean Square | 0.047099 |

| | | |
|---|---|---|
| Number of Means | 2 | 3 |
| Critical Range | .1805 | .1897 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.73792 | 12 | 3 |
| B | 0.50042 | 12 | 2 |
| C | 0.20833 | 12 | 1 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 32 |
| Error Mean Square | 0.047099 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .1474 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.58083 | 18 | 2 |
| B | 0.38361 | 18 | 1 |

**Table A.5** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing 0.032g/ml waxy maize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 1.95727536 | 0.65242512 | 120.22 | <.0001 |
| Error | 31 | 0.16823460 | 0.00542692 | | |
| Corrected Total | 34 | 2.12550996 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.920850 | -26.85800 | 0.073668 | -0.27428 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.89816750 | 0.94908375 | 174.88 | <.0001 |
| X2 | 1 | 0.05910786 | 0.05910786 | 10.89 | 0.0024 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.88495894 | 0.94247947 | 173.67 | <.0001 |
| X2 | 1 | 0.05910786 | 0.05910786 | 10.89 | 0.0024 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 31 |
| Error Mean Square | 0.005427 |
| Harmonic Mean of Cell Sizes | 11.64706 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .06226 | .06543 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | -0.09325 | 12 | 2 |
| A | -0.12045 | 11 | 1 |
| B | -0.59633 | 12 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

Alpha 0.05

Error Degrees of Freedom 31

Error Mean Square 0.005427

Harmonic Mean of Cell Sizes 17.48571.

Number of Means 2

Critical Range .05081

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | -0.23011 | 18 | 2 |
| B | -0.32106 | 17 | 1 |

**Table A.6** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing 0.032g/ml waxy maize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 1.84267062 | 0.61422354 | 81.31 | <.0001 |
| Error | 29 | 0.21908011 | 0.00755449 | | |
| Corrected Total | 32 | 2.06175073 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.893741 | -23.18337 | 0.086917 | -0.37490 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.76309145 | 0.88154573 | 116.69 | <.0001 |
| X2 | 1 | 0.07957917 | 0.07957917 | 10.53 | 0.0030 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 1.79671517 | 0.89835759 | 118.92 | <.0001 |
| X2 | 1 | 0.07957917 | 0.07957917 | 10.53 | 0.0030 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.007554 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .07580 | .07965 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.18345 | 11 | 2 |
| A | 0.24118 | 11 | 1 |
| B | 0.70009 | 11 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.007554 |
| Harmonic Mean of Cell Sizes | 16.48485 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .06192 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | -0.33871 | 17 | 2 |
| B | -0.41338 | 16 | 1 |

**Table A.7** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing 0.040 g/ml waxy maize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 1.84267062 | 0.61422354 | 81.31 | <.0001 |
| Error | 29 | 0.21908011 | 0.00755449 | | |
| Corrected Total | 32 | 2.06175073 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.893741 | -23.18337 | 0.086917 | -0.374909 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| X1 | 2 | 1.76309145 | 0.88154573 | 116.69 | <.0001 |
| X2 | 1 | 0.07957917 | 0.07957917 | 10.53 | 0.0030 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| X1 | 2 | 1.79671517 | 0.89835759 | 118.92 | <.0001 |
| X2 | 1 | 0.07957917 | 0.07957917 | 10.53 | 0.0030 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.007554 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .07580 | .07965 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.18345 | 11 | 2 |
| A | 0.24118 | 11 | 1 |
| B | 0.70009 | 11 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.007554 |
| Harmonic Mean of Cell Sizes | 16.48485 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .06192 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.33871 | 17 | 2 |
| B | 0.41338 | 16 | 1 |

**Table A.8** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing 0.040 g/ml waxy maize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 35.39815621 | 11.79938540 | 105.00 | <.0001 |
| Error | 28 | 3.14663166 | 0.11237970 | | |
| Corrected Total | 31 | 38.54478788 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.918364 | 28.94756 | 0.335231 | 1.15806 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 33.87757461 | 16.93878731 | 150.73 | <.0001 |
| X2 | 1 | 1.52058160 | 1.52058160 | 13.53 | 0.0010 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 34.69545109 | 17.34772554 | 154.37 | <.0001 |
| X2 | 1 | 1.52058160 | 1.52058160 | 13.53 | 0.0010 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 28 |
| Error Mean Square | 0.11238 |
| Harmonic Mean of Cell Sizes | 10.64516 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .2976 | .3127 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 2.5785 | 11 | 3 |
| B | 0.4681 | 10 | 1 |
| B | 0.3648 | 11 | 2 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 28 |
| Error Mean Square | 0.11238 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .2428 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 1.3063 | 16 | 1 |
| B | 1.0099 | 16 | 2 |

**Table A.9** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing 0.048 g/ml waxy maize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 0.98761785 | 0.32920595 | 27.18 | <.0001 |
| Error | 25 | 0.30282271 | 0.01211291 | | |
| Corrected Total | 28 | 1.29044055 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.765334 | -22.02692 | 0.110059 | -0.499655 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 0.97152984 | 0.48576492 | 40.10 | <.0001 |
| X2 | 1 | 0.01608801 | 0.01608801 | 1.33 | 0.2600 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 0.93397145 | 0.46698573 | 38.55 | <.0001 |
| X2 | 1 | 0.01608801 | 0.01608801 | 1.33 | 0.2600 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 25 |
| Error Mean Square | 0.012113 |
| Harmonic Mean of Cell Sizes | 8.155894 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .1122 | .1179 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.39538 | 13 | 2 |
| A | 0.44182 | 11 | 1 |
| B | 0.89800 | 5 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 25 |
| Error Mean Square | 0.012113 |
| Harmonic Mean of Cell Sizes | 13.65517 |

.

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .08675 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.44464 | 11 | 2 |
| B | 0.53328 | 18 | 1 |

**Table A.10** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing 0.048 g/ml waxy maize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 32.46308027 | 10.82102676 | 26.47 | <.0001 |
| Error | 29 | 11.85565791 | 0.40881579 | | |
| Corrected Total | 32 | 44.31873818 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.732491 | 34.75960 | 0.639387 | 1.839455 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 32.38561769 | 16.19280884 | 39.61 | <.0001 |
| X2 | 1 | 0.07746258 | 0.07746258 | 0.19 | 0.6666 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 32.19382849 | 16.09691425 | 39.37 | <.0001 |
| X2 | 1 | 0.07746258 | 0.07746258 | 0.19 | 0.6666 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.408816 |
| Harmonic Mean of Cell Sizes | 10.83333 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .5619 | .5904 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 3.3144 | 10 | 3 |
| B | 1.4556 | 10 | 1 |
| B | 1.0002 | 13 | 2 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.408816 |
| Harmonic Mean of Cell Sizes | 16.48485 |

.

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .4555 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 1.9326 | 16 | 2 |
| A | 1.7518 | 17 | 1 |

**Table A.11** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing 0.064 g/ml amylomaize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 3.34749573 | 1.11583191 | 258.48 | <.0001 |
| Error | 21 | 0.09065638 | 0.00431697 | | |
| Corrected Total | 24 | 3.43815211 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.973632 | -14.04873 | 0.065704 | -0.467684 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 3.33265501 | 1.66632751 | 385.99 | <.0001 |
| X2 | 1 | 0.01484072 | 0.01484072 | 3.44 | 0.0778 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 3.21259787 | 1.60629894 | 372.09 | <.0001 |
| X2 | 1 | 0.01484072 | 0.01484072 | 3.44 | 0.0778 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 21 |
| Error Mean Square | 0.004317 |
| Harmonic Mean of Cell Sizes | 7.636364 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .06993 | .07341 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.05771 | 7 | 2 |
| B | 0.19268 | 6 | 1 |
| C | 0.84433 | 12 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 21 |
| Error Mean Square | 0.004317 |
| Harmonic Mean of Cell Sizes | 12.32 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .05505 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.40257 | 14 | 2 |
| B | 0.55055 | 11 | 1 |

**Table A.12** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing 0.064 g/ml amylomaize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 88.65596234 | 29.55198745 | 407.12 | <.0001 |
| Error | 23 | 1.66950578 | 0.07258721 | | |
| Corrected Total | 26 | 90.32546813 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.981517 | 14.50014 | 0.269420 | 1.858052 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 87.35653605 | 43.67826802 | 601.74 | <.0001 |
| X2 | 1 | 1.29942629 | 1.29942629 | 17.90 | 0.0003 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 84.42594552 | 42.21297276 | 581.55 | <.0001 |
| X2 | 1 | 1.29942629 | 1.29942629 | 17.90 | 0.0003 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 23 |
| Error Mean Square | 0.072587 |
| Harmonic Mean of Cell Sizes | 8.542373 |

.

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .2697 | .2832 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 3.8683 | 12 | 3 |
| B | 0.3152 | 8 | 1 |
| B | 0.1752 | 7 | 2 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 23 |
| Error Mean Square | 0.072587 |
| Harmonic Mean of Cell Sizes | 13.33333 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .2159 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 2.3006 | 12 | 1 |
| B | 1.5040 | 15 | 2 |

**Table A.13** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing 0.072 g/ml amylomaize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 4.93901476 | 1.64633825 | 59.96 | <.0001 |
| Error | 30 | 0.82365160 | 0.02745505 | | |
| Corrected Total | 33 | 5.76266636 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.857071 | -28.35612 | 0.165696 | -0.58433 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 4.66672141 | 2.33336070 | 84.99 | <.0001 |
| X2 | 1 | 0.27229335 | 0.27229335 | 9.92 | 0.0037 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 4.60624629 | 2.30312314 | 83.89 | <.0001 |
| X2 | 1 | 0.27229335 | 0.27229335 | 9.92 | 0.0037 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 30 |
| Error Mean Square | 0.027455 |
| Harmonic Mean of Cell Sizes | 11.31429 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | .1423 | .1495 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.28800 | 12 | 2 |
| A | 0.37436 | 11 | 1 |
| B | 1.11759 | 11 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 30 |
| Error Mean Square | 0.027455 |
| Harmonic Mean of Cell Sizes | 16.94118 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .1163 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.47941 | 16 | 2 |
| B | 0.67761 | 18 | 1 |

**Table A.14** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing 0.072 g/ml amylomaize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 171.8619816 | 57.2873272 | 59.67 | <.0001 |
| Error | 30 | 28.8032914 | 0.9601097 | | |
| Corrected Total | 33 | 200.6652730 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.856461 | 40.11724 | 0.979852 | 2.442471 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 161.1366260 | 80.5683130 | 83.92 | <.0001 |
| X2 | 1 | 10.7253556 | 10.7253556 | 11.17 | 0.0022 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 159.1714776 | 79.5857388 | 82.89 | <.0001 |
| X2 | 1 | 10.7253556 | 10.7253556 | 11.17 | 0.0022 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 30 |
| Error Mean Square | 0.96011 |
| Harmonic Mean of Cell Sizes | 11.31429 |

| | | |
|---|---|---|
| Number of Means | 2 | 3 |
| Critical Range | .8414 | .8842 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 5.5899 | 11 | 3 |
| B | 0.9861 | 11 | 1 |
| B | 0.8923 | 12 | 2 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 30 |
| Error Mean Square | 0.96011 |
| Harmonic Mean of Cell Sizes | 16.94118 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .6876 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 3.0185 | 18 | 1 |
| B | 1.7945 | 16 | 2 |

**Table A.15** ANOVA and Duncan Double Range Test of cohesiveness of lactose free desserts containing 0.080 g/ml amylomaize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 6.08817736 | 2.02939245 | 113.43 | <.0001 |
| Error | 29 | 0.51885070 | 0.01789140 | | |
| Corrected Total | 32 | 6.60702806 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.921470 | -23.53150 | 0.133759 | -0.5684 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 5.99049848 | 2.99524924 | 167.41 | <.0001 |
| X2 | 1 | 0.09767888 | 0.09767888 | 5.46 | 0.0266 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 6.01345517 | 3.00672758 | 168.05 | <.0001 |
| X2 | 1 | 0.09767888 | 0.09767888 | 5.46 | 0.0266 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.017891 |
| Harmonic Mean of Cell Sizes | 10.93923 |

| | | |
|---|---|---|
| Number of Means | 2 | 3 |
| Critical Range | .1170 | .1229 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 0.23767 | 12 | 2 |
| A | 0.34509 | 11 | 1 |
| B | 1.21100 | 10 | 3 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 29 |
| Error Mean Square | 0.017891 |
| Harmonic Mean of Cell Sizes | 16.48485 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .09529 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 0.51938 | 16 | 2 |
| A | 0.61459 | 17 | 1 |

**Table A.16** ANOVA and Duncan Double Range Test of firmness of lactose free desserts containing 0.080 g/ml amylomaize and different types and concentrations of gums

**Samples:** X1- 1 (guar gum), 2 (arabic gum) and 3 (κ-carrageenan); X2- 1 (1% gum concentration) and 2 (0.5% gum concentration)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 248.0979442 | 82.6993147 | 64.19 | <.0001 |
| Error | 28 | 36.0711920 | 1.2882569 | | |
| Corrected Total | 31 | 284.1691362 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.873064 | 46.24770 | 1.135014 | 2.4542 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 234.4394029 | 117.2197014 | 90.99 | <.0001 |
| X2 | 1 | 13.6585413 | 13.6585413 | 10.60 | 0.0030 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 2 | 241.1222714 | 120.5611357 | 93.58 | <.0001 |
| X2 | 1 | 13.6585413 | 13.6585413 | 10.60 | 0.0030 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 28 |
| Error Mean Square | 1.288257 |
| Harmonic Mean of Cell Sizes | 10.51327 |

| Number of Means | 2 | 3 |
|---|---|---|
| Critical Range | 1.014 | 1.066 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X1 |
|---|---|---|---|
| A | 6.7785 | 9 | 3 |
| B | 0.8789 | 11 | 1 |
| B | 0.6550 | 12 | 2 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 28 |
| Error Mean Square | 1.288257 |

| | |
|---|---|
| Number of Means | 2 |
| Critical Range | .8220 |

Means with the same letter are not significantly different.

| Duncan Grouping | Mean | N | X2 |
|---|---|---|---|
| A | 2.9211 | 16 | 1 |
| B | 1.9873 | 16 | 2 |

**Table A.17** ANOVA and Duncan Double Range Test of T2 of lactose free desserts containing different types of gums and different waxy maize concentrations

**Samples:** Starch content- 1 (0.032g/ml), 2 (0.040g/ml) and 3 (0.048g/ml); Gum type- No gum (lactose free dessert with low sucrose concentration), Guar (guar), Carrageenan (κ-carrageenan), Gum arabic (arabic gum)

**General Linear Model: T2 versus Starch Content, Gum Type**

| Factor | Type | Levels | Values |
|---|---|---|---|
| StarchContent | fixed | 3 | 1, 2, 3 |
| GumType | fixed | 4 | Guar, Gum Arabic, Carragenan, No Gum |

Analysis of Variance for T2, using Adjusted SS for Tests

| Source | DF | Seq SS | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|---|
| StarchContent | 2 | 1144.40 | 778.85 | 389.42 | 41.75 | 0.000 |
| GumType | 3 | 120.64 | 120.64 | 40.21 | 4.31 | 0.011 |
| StarchContent*GumType | 6 | 559.41 | 559.41 | 93.23 | 10.00 | 0.000 |
| Error | 33 | 307.80 | 307.80 | 9.33 | | |
| Total | 44 | 2132.25 | | | | |

S = 3.05407 R-Sq = 85.56% R-Sq(adj) = 80.75%

Grouping Information Using Tukey Method and 95.0% Confidence

| StarchContent | N | Mean | Grouping |
|---|---|---|---|
| 1 | 15 | 142.0 | A |
| 2 | 15 | 136.3 | B |
| 3 | 15 | 131.4 | C |

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

| GumType | N | Mean | Grouping |
|---|---|---|---|
| Guar | 9 | 138.8 | A |
| Carragenan | 9 | 137.6 | AB |
| NoGum | 18 | 134.9 | B |
| GumArabic | 9 | 134.7 | B |

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95.0% Confidence

| StarchContent | GumType | N | Mean | Grouping |
|---|---|---|---|---|
| 1 | Guar | 3 | 147.8 | A |
| 1 | NoGum | 6 | 144.8 | A |
| 2 | Carragenan | 3 | 142.9 | A B |
| 1 | Carragenan | 3 | 139.3 | A B C |
| 1 | GumArabic | 3 | 136.2 | B C |
| 2 | GumArabic | 3 | 135.3 | B C |
| 3 | Guar | 3 | 134.7 | B C |
| 2 | NoGum | 6 | 134.6 | C |
| 3 | GumArabic | 3 | 132.7 | C D |
| 3 | Carragenan | 3 | 132.5 | C D |
| 2 | Guar | 3 | 132.4 | C D |
| 3 | NoGum | 6 | 125.7 | D |

Means that do not share a letter are significantly different.

**Table A.18** ANOVA and Duncan Double Range Test of acceptability of taste of different formulations made with waxy maize starch

**Samples:** Dessert formulations- 1 (lactose containing dessert with 0.040g/ml waxy maize starch), 2 (lactose free dessert that contain 0.040g/ml waxy maize and 0.10g/ml), 3 (lactose free dessert that contain 0.040g/ml waxy maize and 0.14g/ml), 4 (lactose free dessert that contain 0.040g/ml waxy maize starch + 0.5% κ-carrageenan), 5 (lactose free dessert that contain 0.032g/ml waxy maize and 0.5% κ-carrageenan)

The SAS System

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| X1 | 5 | 1 2 3 4 5 |

| | |
|---|---|
| Number of Observations Read | 75 |
| Number of Observations Used | 75 |

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 15.6000000 | 3.9000000 | 2.72 | 0.0364 |
| Error | 70 | 100.4000000 | 1.4342857 | | |
| Corrected Total | 74 | 116.0000000 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.134483 | 35.22402 | 1.197617 | 3.400000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 4 | 15.60000000 | 3.90000000 | 2.72 | 0.0364 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 4 | 15.60000000 | 3.90000000 | 2.72 | 0.0364 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 70 |
| Error Mean Square | 1.434286 |

| Number of Means | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Critical Range | .8722 | .9176 | .9477 | .9696 |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | X1 |
|---|---|---|---|---|
| | A | 3.9333 | 15 | 5 |
| | A | 3.7333 | 15 | 4 |
| B | A | 3.4000 | 15 | 2 |
| B | A | 3.3333 | 15 | 1 |
| B | | 2.6000 | 15 | 3 |

**Table A.19** ANOVA and Duncan Double Range Test of acceptability of taste of different dessert formulations made with waxy maize starch

**Samples:** Dessert formulations- 1 (lactose containing dessert with 0.040g/ml waxy maize starch), 2 (lactose free dessert that contain 0.040g/ml waxy maize and 0.10g/ml), 3 (lactose free dessert that contain 0.040g/ml waxy maize and 0.14g/ml), 4 (lactose free dessert that contain 0.040g/ml waxy maize starch + 0.5% κ-carrageenan), 5 (lactose free dessert that contain 0.032g/ml waxy maize and 0.5% κ-carrageenan)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 23.7866667 | 5.9466667 | 5.05 | 0.0012 |
| Error | 70 | 82.4000000 | 1.1771429 | | |
| Corrected Total | 74 | 106.1866667 | | | |

R-Square Coeff Var Root MSE Y Mean

| | | | |
|---|---|---|---|
| 0.224008 | 33.34925 | 1.084962 | 3.253333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 4 | 23.78666667 | 5.94666667 | 5.05 | 0.0012 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 4 | 23.78666667 | 5.94666667 | 5.05 | 0.0012 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 70 |
| Error Mean Square | 1.177143 |

| Number of Means | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Critical Range | .7902 | .8313 | .8585 | .8784 |

Means with the same letter are not significantly different.

| Duncan Grouping | | Mean | N | X1 |
|---|---|---|---|---|
| | A | 4.2000 | 15 | 2 |
| | B | 3.4000 | 15 | 1 |
| C | B | 3.2667 | 15 | 3 |
| C | B | 2.8667 | 15 | 5 |
| C | | 2.5333 | 15 | 4 |

**Table A.20** ANOVA and Duncan Double Range Test of acceptability of texture of different dessert formulations made with waxy maize starch

**Samples:** Dessert formulations- 1 (lactose containing dessert with 0.040g/ml waxy maize starch), 2 (lactose free dessert that contain 0.040g/ml waxy maize and 0.10g/ml), 3 (lactose free dessert that contain 0.040g/ml waxy maize and 0.14g/ml), 4 (lactose free dessert that contain 0.040g/ml waxy maize starch + 0.5% κ-carrageenan), 5 (lactose free dessert that contain 0.032g/ml waxy maize and 0.5% κ-carrageenan)

The SAS System

The GLM Procedure

Dependent Variable: Y

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 4 | 23.7866667 | 5.9466667 | 5.05 | 0.0012 |
| Error | 70 | 82.4000000 | 1.1771429 | | |
| Corrected Total | 74 | 106.1866667 | | | |

| R-Square | Coeff Var | Root MSE | Y Mean |
|---|---|---|---|
| 0.224008 | 33.34925 | 1.084962 | 3.253333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 4 | 23.78666667 | 5.94666667 | 5.05 | 0.0012 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| X1 | 4 | 23.78666667 | 5.94666667 | 5.05 | 0.0012 |

The SAS System

The GLM Procedure

Duncan's Multiple Range Test for Y

| | |
|---|---|
| Alpha | 0.05 |
| Error Degrees of Freedom | 70 |
| Error Mean Square | 1.177143 |

| Number of Means | 2 | 3 | 4 | 5 |
|---|---|---|---|---|
| Critical Range | .7902 | .8313 | .8585 | .8784 |

| Duncan Grouping | | Mean | N | X1 |
|---|---|---|---|---|
| | A | 4.2000 | 15 | 2 |
| | B | 3.4000 | 15 | 1 |
| C | B | 3.2667 | 15 | 3 |
| C | B | 2.8667 | 15 | 5 |
| C | | 2.5333 | 15 | 4 |