EFFECTS OF XANTHAN AND GUAR GUMS ON QUALITY AND STALING OF GLUTEN FREE CAKES BAKED IN MICROWAVE-INFRARED COMBINATION OVEN

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EFFECTS OF XANTHAN AND GUAR GUMS ON QUALITY AND STALING OF GLUTEN FREE CAKES BAKED IN MICROWAVE-INFRARED COMBINATION OVEN

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ABSTRACT

EFFECTS OF XANTHAN AND GUAR GUMS ON QUALITY AND STALING OF GLUTEN FREE CAKES BAKED IN MICROWAVE-INFRARED COMBINATION OVEN

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The objective of this study was to determine the effects of different gums, gum concentrations and their combination on quality and staling of gluten free cakes baked in microwave-infrared combination oven and conventional oven.

In the first part of the study, the effects of different gums (xanthan and guar gum) at different concentrations (0.3%, 0.6% and 1.0%) and their blend on quality of gluten free cakes baked in microwave-infrared combination and conventional oven were investigated. The gelatinization properties of the cakes were also investigated.

Among different gums, xanthan-guar gum blend addition to the cake formulation improved cake quality with increasing specific volume as well as decreasing weight loss and crumb hardness values for both types of baking methods. Gum blend addition also improved the cake acceptability in terms of texture, taste and the crust color of the cakes. The gelatinization degrees of cakes were found to decrease as the gum concentration increased, for both types of ovens.

In the second part of the study it was focused on effects of different gums, gum concentrations and storage times on staling of cakes. Addition of gum blend decreased hardness, weight loss, retrogradation enthalpy and the change in setback viscosity values of cakes for both types of ovens and slowed down staling for 2 and 3 days for cakes baked in microwave-infrared combination and conventional oven, respectively. In microwave-infrared combination oven, it was possible to produce gluten-free cakes with similar quality with the conventionally baked ones even in a 75% shorter baking time.

Keywords: Cake baking, Gum, Infrared, Microwave, Staling

ÖZ

KSANTAN VE GUAR GAMLARIN MİKRODALGA- KIZILÖTESİ KOMBİNASYON FIRINDA PİŞİRİLEN KEKLERİN KALİTE VE BAYATLAMALARI ÜZERİNE ETKİLERİ

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Bu çalışmanın amacı, farklı gamların, gam konsantrasyonlarının ve gam karışımının mikrodalga-kızılötesi kombinasyon ve konvansiyonel fırında pişirilen glutensiz keklerin kalite ve bayatlamaları üzerine olan etkilerinin belirlenmesidir.

Çalışmanın ilk kısmında, farklı gamların (ksantan ve guar gam) farklı konsantrasyonlarının (0.3%, 0.6% ve 1.0%) ve bu gamların karışımının mikrodalga-kızılötesi kombinasyon ve konvansiyonel fırında pişirilen glutensiz keklerin kaliteleri üzerine olan etkileri incelenmiştir. Ayrıca, keklerin jelatinizasyon özellikleri belirlenmiştir.

Farklı gam çeşitleri arasında, ksantan-guar gam karışımının ilavesi, her iki pişirme yönteminde de keklerin özgül hacim değerlerini arttırıp, ağırlık kaybı ve iç sertlik değerlerini azaltarak kek kalitesini iyileştirmiştir. Gam karışımının ilavesi ayrıca keklerin tekstür, tat ve kabuk renkleri açısından beğenirliğini arttırmıştır. Her iki fırında pişirilen kekler için de, gam konsantrasyonu arttıkça, keklerin jelatinizasyon dereceleri azalmıştır.

Çalışmanın ikinci kısmında farklı gamların, gam konsantrasyonlarının ve depolama sürelerinin, bayatlama üzerine etkilerine odaklanılmıştır. Gam karışımının ilavesi her iki fırın tipi için, keklerin iç sertlik, ağırlık kaybı, retrogradasyon entalpisi ve katılaşma viskozitesi değerlerini düşürmüş ve bayatlamayı mikrodalga-kızılötesi kombinasyon ve konvansiyonel fırınlarda, sırasıyla 2 ve 3 gün yavaşlatmıştır. Mikrodalga-kızılötesi kombinasyon fırın ile konvansiyonel fırında pişirilen keklere benzer kalitede glutensiz kek üretimi, üstelik pişme süresi % 75 oranında azalarak mümkün olmuştur.

Anahtar sözcükler: Kek pişirme, Gam, Kızılötesi, Mikrodalga, Bayatlama

To My Family

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LIST OF ABBREVIATIONS

AACC	American Association of Cereal Chemists
AOAC	Association of Official Agricultural Chemists
DSC	Differential Scanning Calorimetry
ΔE	Total color change (Euclidean distance in CIE *L*a*b** space)
ΔH	Enthalpy change
IR	Infrared
MW	Microwave
ppm	Parts per million
RVA	Rapid Visco Analyzer
TPA	Texture Profile Analysis
V	Volume
W	Weight

CHAPTER 1

INTRODUCTION

1.1. Gluten and Its Role in Baking

The gluten proteins are the storage proteins of wheat. They are easy to isolate in relatively pure form because they are insoluble in water. The starch and the water soluble components can be removed from gluten by gently washing dough under a small stream of water. After washing, a rubbery ball of gluten is left. As isolated from flour, gluten contains (on a dry basis) about 80% protein and 8% lipids, with the remainder being ash and carbohydrate (Hoseney, 1986).

When wheat flour is mixed with water, a cohesive, viscoelastic dough is formed. Gluten is the main structure forming protein in flour, responsible for the elastic and extensible properties needed to produce good quality products (Gallagher et al., 2004). It is generally believed that the gluten proteins are responsible not only for this cohesive, viscoelastic property of wheat flour dough but also for the dough's ability to retain gas during fermentation and partly for the setting of the dough during baking (Hoseney, 1986).

The properties of dough are essentially those of hydrated gluten (Bloksma and Bushuk, 1980). Gluten is a composite of the proteins gliadin (a prolamin) and glutenin (a glutelin). The gliadins are a large group of proteins that are extremely sticky when hydrated. They have almost no resistance to extension and appear to be responsible for the dough's cohesiveness. The glutenin proteins give dough its property of resistance to extension (Hoseney, 1986). Together, the two give kneaded dough its elasticity, allow leavening and contribute chewiness to baked products like bagels (Presutti et al., 2007).

1.1.1. Gluten Intolerance

Gluten is an important source of nutritional proteins, both in foods prepared directly from sources containing it, and as an additive to foods otherwise low in protein (Hill et al., 1995). However, there are rising demands for gluten free products owing to the apparent or real increase in celiac disease, or other allergic reactions/intolerances to gluten consumption. Celiac disease is related to the inflammation of the small intestine leading to malabsorption of several important nutrients and intestinal mucosal damage. The only effective treatment for celiac disease is a strict adherence to a gluten free diet throughout the patient's lifetime, which in time, results in clinical and mucosal recovery (Lazaridou et al., 2007). The manifestations of celiac disease range from no symptoms to malabsorption of nutrients with involvement of multiple organ systems (Hill et al., 1995).

Gluten is a generic term for proteins found in wheat, barley, rye and oat. Each grain has a specific gluten-like protein (gliadin in wheat, hordein in barley, secalin in rye, and avenin in oat) which contains amino acid sequences that can be harmful to people with celiac disease and any gluten intolerance (Niewinski, 2008).

Wheat supplies much of the world's dietary protein and food supply. However, as much as 1/200- 1/350 of the population of Europe, 1/250- 1/500 of the population of the USA, and 1/300- 1/500 of the population of Turkey suffer from celiac disease (Tandoruk, 2005).

1.1.2. Gluten Free Product Development

Throughout the history, rice has been one of the most important foods in the human diet and one of the most comprehensive cereal crops (9% of the total cultivated soil). In fact, rice has probably fed more people in history than any other crop. Even today, rice grains sustain two-thirds of the world's population, approximately 2.5 billion people (Rosell and Marco, 2008). Rice flour has been found to be one of the most suitable cereal grain flours for preparing foods for celiac patients. Rice possesses unique nutritional, hypoallergenic, colorless and pleasant taste properties hence; its use in baby foods, puddings and especially in development of foods for gluten intolerant patients has been increasing (Gujral and Rosell, 2004). Since rice is a gluten free cereal, it has a promising and encouraging future value in gluten free product development.

One of the most important parts of gluten free product development is keeping the ingredients and the final product free from gluten. In order to achieve that, contamination tests should be performed throughout the production line. "Gluten free" food products are defined in Codex Alimentarius guidelines as containing <200 ppm gluten for cereal derived and <20 ppm for non-cereal derived foods (Codex Standard 118, 1979). AOAC 991.19 method (AOAC, 1995) is the formally validated method for the determination of relatively high levels of gluten in food and its raw materials. Contamination tests can be performed by using gluten assay kits. The Gluten Assay kits are intended for the detection and quantification of gluten at very low concentrations in uncooked and cooked foods. The assay utilizes antibodies to gliadin protein in a non-competitive, sandwich type ELISA. The ready to use standards provide accurate quantification in parts per million (ppm).

The removal of gluten from bakery products deteriorates quality. The replacement of gluten presents a major technological challenge, since gluten is an essential structure-building protein, contributing to the appearance and crumb structure of many baked products. To ensure the quality of gluten free products, the loaves must have quality characteristics similar to those of wheat flour products. Therefore, use of polymeric substances such as hydrocolloids, that mimic the viscoelastic properties of gluten is often required (Gallagher et al., 2003).

In recent years there has been increasing interest in gluten free breads, mainly involving the approach of incorporation of starches, hydrocolloids, proteins and other cereal flours (rice and/or corn flour) into a gluten free flour base that could mimic the viscoelastic properties of gluten. As a result, bakery products with acceptable structure, mouth feel and shelf-life are obtained (Lazaridou et al., 2007). Ozboy (2002) investigated the development methods of corn starch bread containing gums for phenylketonuria patients. Sivaramakrishnan et al. (2004) studied the rheological properties of rice dough for making rice bread. Schober et al. (2008) studied the rheology and microstructure of starch doughs containing zein for leavened gluten free breads. Korus et al. (2009) studied the impact of resistant starch on characteristics of gluten free dough and bread. Clerici et al. (2009) studied the production of acidic extruded rice flour and its influence on the qualities of gluten free bread. However, in the literature, there is only limited number of studies on gluten free products other than bread. Huang and Rooney (2001) performed a response surface methodology study to produce gluten free pasta. Arendt et al. (2002) investigated the effects of different starches on the formulation of gluten free biscuits. Chuang and Yeh (2006) studied the rheological characteristics and texture attributes of glutinous rice cakes. Ji et al. (2007) studied the staling of cakes prepared from rice flour and sticky rice flour. Turabi et al. (2008) studied the rheological properties of rice cake formulations containing different gums. Yalcin and Basman (2008a, 2008b) studied the effects of gelatinization level, gums and transglutaminase on the quality characteristics of rice noodle and corn noodles.

1.2. Hydrocolloids Used in Bakery Products

Hydrocolloids are water-soluble polysaccharides with high molecular weights. Since they can function at very low concentrations, their use may be helpful to achieve cost reductions and their properties make them suitable for use in a wide variety of applications in the food industry (Ward and Andon, 2002). They are able to improve food texture, retard starch retrogradation, improve moisture retention and enhance the overall quality of the products during storage (Stauffer, 1990).

The function of gums is very application-sensitive (Heflich, 1996). The functionality of gums is affected by many factors, such as chemical nature of the gum, temperature, pH range, concentration, particle size, presence of other inorganic ions, and chelating agents (Ward and Andon, 2002).

Gums are used in bakery products primarily to enhance final product moistness. Gums absorb several times of their weight in water. However, the overall increase in dough water absorption due to the addition of a gum is relatively small because gums are being used at low concentrations (typically from 0.01% to 0.5% on total formula basis). The additional water may be insignificant, but the viscous, slippery mouth feel that the gums retain even after baking can be perceived as a beneficial increase in product moistness. Gums can make the baked crumb rubbery and elastic. This may be perceived as softer or fresher at sufficiently low levels, and also as tough or chewy at elevated levels (Heflich, 1996).

The softening effect of hydrocolloids should be attributed to their water retention capacity, a possible inhibititor of the amylopectin retrogradation (Guarda et al., 2004). Davidou et al. (1996) reported that both degrees of crumb firmness and the rate of staling during storage were reduced by addition of locust bean gum, alginate, and xanthan. Lent and Grant (2001) found that bagels containing xanthan had slightly higher crumb moisture contents and staled at a somewhat reduced rate. There are studies in the literature about the effects of different hydrocolloids on the quality of conventionally baked breads (Rosell et al., 2001; Guarda et al., 2004; Ribotta et al., 2005). Rosell et al. (2001) investigated the effects of different hydrocolloids (sodium alginate, κ- carrageenan, xanthan gum and hydroxypropyl methylcellulose (HPMC)) on the final quality of breads. They demonstrated that hydrocolloids except alginate increased the specific volume as well as moisture retention. The effect of hydrocolloids (sodium alginate, κ- carrageenan, xanthan gum and HPMC) on fresh bread quality and bread staling were studied by Guarda et al. (2004) and it was found that bread quality was improved with the usage of these hydrocolloids. Additionally, they found that all hydrocolloids were able to reduce the loss of moisture content during storage. According to Ribotta et al. (2005) dough rheology and bread quality were affected in different ways by the addition of hydrocolloids. They reported that all the hydrocolloids tested decreased the initial bread crumb firmness and chewiness. The effects of gums (xanthan and guar) at different concentrations on fresh and frozen microwave-reheated breads were studied by Mandala (2005). Use of gums (xanthan gum, guar gum and methylcellulose) retarded staling of microwave-baked cakes also

(Seyhun et al., 2003). In the present study, quality parameters such as weight loss, specific volume and hardness, were found to be dependent on gum type and gum concentration for cakes baked in MW-IR combination oven and conventional oven. Among the gums studied, the addition of xanthan-guar gum blend to the formulation resulted in an increase in specific volume as well as a decrease in weight loss and hardness of the cakes when compared with the control cakes. In addition to these, the xanthan-guar gum blend retarded the staling of the cakes baked in both types of ovens.

Hydrocolloids have been used as gluten substitutes in the formulation of gluten free breads due to their polymeric structure (Ylimaki et. al, 1988). However, relatively little research (Miller and Setser, 1982; Miller and Hoseney, 1990; Donelson et al., 2000; Arozarena et. al, 2001) has been conducted to analyze the influence of hydrocolloids on cake baking.

Some of the gums are not preferred to be used in dough/batter formulations because of their cost. Xanthan and guar can sufficiently function at very low levels to be cost-effective. Turabi et al. (2008) studied the rheological properties of batters and quality of rice cakes formulated with different gums and an emulsifier blend and obtained the best results (in terms of emulsion stability and apparent viscosity of cake batter; texture, volume and porosity of the cakes) for xanthan gum and guar gum. In addition to these, they also observed a synergistic interaction between xanthan and guar gum resulting in higher apparent viscosity of cake batters as compared to other gums. Therefore, in this study, for cake batter modification, xanthan gum and guar gum at different concentrations were chosen.

1.2.1. Xanthan Gum

Xanthan gum is a polysaccharide derived from *Xanthomonas campestris*, a bacterium commonly found on leaves of plants of the cabbage family (BeMiller and Whistler, 1996). Xanthan gum has a β-D-glucose backbone, but every second glucose unit is attached to a trisaccharide consisting of mannose, glucuronic acid, and mannose (Figure 1.1).

Xanthan solutions display unique rheological properties and excellent mechanical, chemical and enzymatic stability, solubility in hot or cold water, high solution viscosity at low concentrations. Xanthan is used as a thickening agent or as a stabilizer in food applications (BeMiller and Whistler, 1996). In addition to these, it is used to improve quality (Rosell et al., 2001; Guarda et al., 2004; Mandala, 2005; Ribotta et al., 2005; Gavilighi et al., 2006) and to extend shelf-life (Guarda et al., 2004; Gavilighi et al., 2006) of breads baked in conventional ovens.

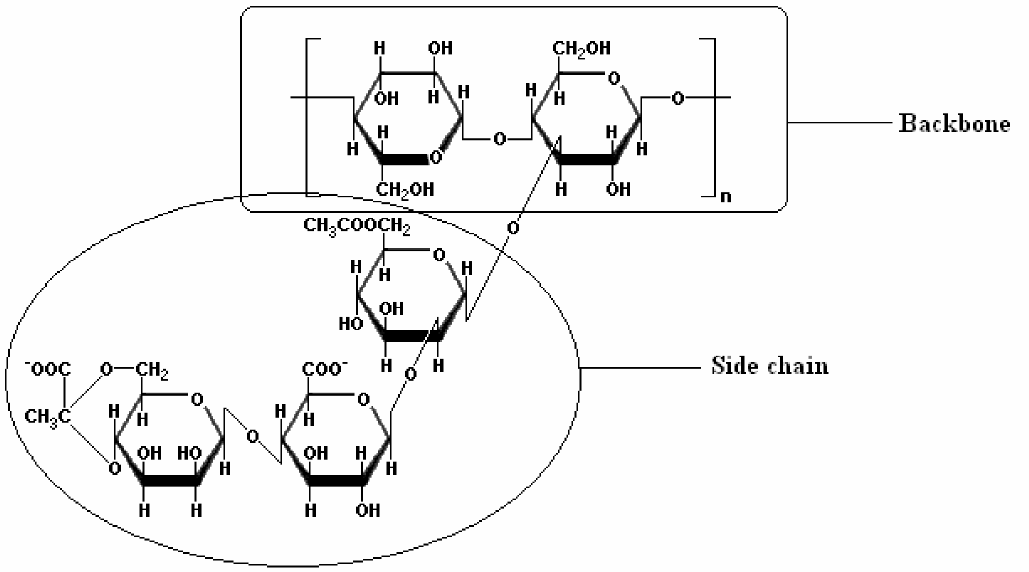


Figure 1.1 Structure of xanthan gum (Adapted from BeMiller and Whistler, 1996)

In the literature, xanthan gum has been widely used as an ingredient, for investigation of cake quality and shelf life. Miller and Setser (1982) studied xanthan gum in a reduced-egg-white angel food cake. Miller and Hoseney (1990) studied the role of xanthan gum in white layer cakes. Gomez et al. (2007) studied the functionality of different hydrocolloids (including xanthan gum) on the quality and shelf-life of yellow layer cakes. Turabi et al. (2008) investigated the rheological properties and quality of rice cakes formulated with different gums (including xanthan gum) and an emulsifier blend.

1.2.2. Guar Gum

Guar gum is a cold water soluble, nonionic, and salt tolerant natural polysaccharide. It is the ground endosperm of seeds from guar plant (*Cyamopsis tetragonoloba*). The main component of endosperm is a galactomannan. Galactomannans consist of a main chain of β-D-mannopyranosyl units joined by 1,4 bonds with single unit α-D-galactopyranosyl branches attached at O-6. The specific polysaccharide component of guar gum is guaran (Figure 1.2). In guaran, about one half of the D-mannopyranosyl main chain units contain a D-galactopyranosyl side chain (BeMiller and Whistler, 1996). Guar gum is an important low-cost thickening polysaccharide for both food and non food applications. It has many uses as a food stabilizer and as a source of dietary fiber. It is an excellent additive in salad dressings, ice cream mixes and bakery products because of its strong hydrophilic character (Berk, 1976).

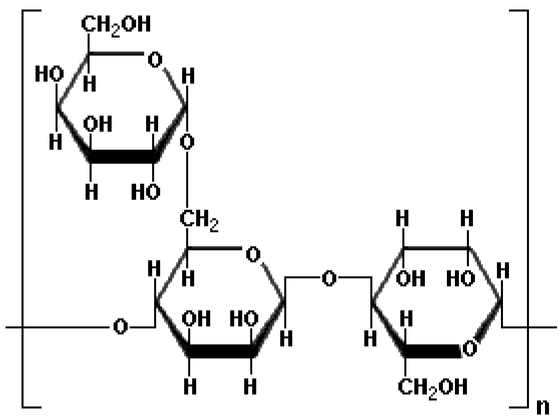


Figure 1.2 Guaran, specific polysaccharide component in guar gum (Adapted from BeMiller and Whistler, 1996)

Guar gum was shown to improve quality of breads (Mandala, 2005; Ribotta et al., 2005; Gavilighi et al., 2006). Gavilighi et al. (2006) used guar gum in retarding staling of lavash breads. Guar gum is functional at the levels of 0.10-0.35% total formula basis and may cause a rubbery crumb at high levels in some products (Ozkoc, 2008).

In the literature guar gum has been used as an ingredient, for investigation of cake quality and shelf life. Gomez et al. (2007) studied the functionality of different hydrocolloids (including guar gum) on the quality and shelf-life of yellow layer cakes and Turabi et al. (2006) investigated the rheological properties and quality of rice cakes formulated with different gums (including guar gum) and an emulsifier blend.

1.2.3. Synergy between Xanthan Gum and Guar Gum

Synergies between hydrocolloids enable to improve or create modified functional properties by using two or more gums together (Ward and Andon, 2002). Guar gum interacts synergistically with xanthan and the synergistic effect is explained by different models.

One of the models is the association of unsubstituted regions of galactomannan with the backbone of the xanthan helix (Dea et al., 1977; Morris et al., 1977; Sworn, 2000; Gurkin, 2002). The intermolecular binding between xanthan and galactomannans suggests that xanthan and galactomannan binding was facilitated by destabilization of the xanthan helix (Cheetham and Mashimba, 1988, 1991). It was demonstrated by the researchers that galactomannan acted like a denaturant to disturb the helix-coil equilibrium of xanthan and displaced ordered conformation of xanthan to the conformation for efficient binding (Morris et. al., 1994). The results obtained in a recent study by Wang et al. (2002) indicated that the intermolecular binding occurred between xanthan and guar molecules, and guar forced xanthan to change from a stiff ordered helix to a more flexible conformation. It was concluded by Wang et al. (2002) that the stability of xanthan helical structure or xanthan chain flexibility played a critical role in its interaction with guar.

Another model assumed that regularly substituted mannan chains with galactose units located on one side of the backbone are linked with the xanthan backbone. This model does not discard the former model but provides an explanation for the interactions of xanthan with highly substituted galactomannans like guar gum (McCleary, 1979; McCleary et al., 1984; Schorsh et al., 1997). On the other hand, Bresolin et al. (1997) reported that there were strong interactions between xanthan (whatever its conformation) and totally substituted galactomannan backbone, assuming different mechanisms were involved between the two polysaccharides. In another study by Schorsch et al. (1997), the influence of parameters such as; xanthan/galactomannan ratio, galactose content, and molecular weight of galactomannan and ionic strength of the medium on viscoelastic properties of xanthan/galactomannan mixtures were examined. The results provided evidence that xanthan gum played a major role in the rheological behavior of xanthan/galactomannan systems. They indicated that differences in the mechanism may exist according to the mannose/galactose ratio, xanthan/galactomannan ratio and the ionic strength.

1.3. Microwave-infrared (MW-IR) Combination Baking of Foods

MW-IR combination baking is a new technology that combines the time saving advantage of microwave heating with the browning and crisping advantages of infrared heating (Keskin et al., 2004a). The schematic representation of a MW-IR combination oven is shown in Figure 1.3 (Adapted from Sumnu and Sahin, 2005).

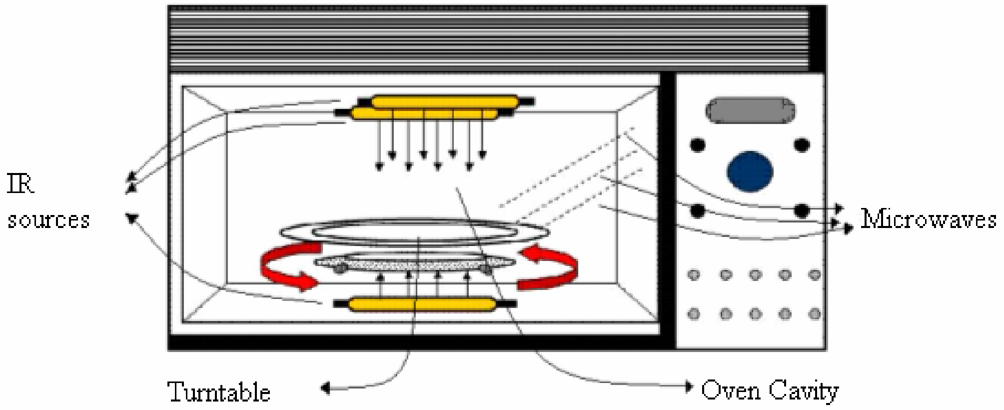


Figure 1.3 The schematic representation of a MW-IR combination oven (Adapted from Sumnu and Sahin 2005)

MW-IR combination heating includes two different heating mechanisms together. In MW-IR combination heating, infrared heating can act at different times and at different locations relative to microwave heating, which increase the uniformity and the overall rate of heating (Datta et al., 2005). The selectivity of the combination heating can also be used to improve moisture distribution inside the food, by heating the surface of a food faster, which can help removing moisture easily from the surface and keeping it crisp (Datta et al., 2005).

There are limited studies on MW-IR combination heating in the literature (Demirekler et al., 2004; Keskin et al., 2004a; Keskin et al., 2004b; Sumnu et al., 2005; Demirkol, 2007; Datta et al., 2007). These studies are about the investigation of the effect of this heating method on quality (texture, volume and color) of breads (Keskin et al, 2004a; Demirekler et al, 2004) and cakes (Sumnu et al, 2005; Demirkol, 2007). Demirekler et al. (2004) found out that, breads baked in MW-IR combination oven had comparable quality with conventionally baked ones in terms of color, textural characteristics, specific volume and porosity. Sumnu et al. (2005) studied the microwave, infrared and MW-IR combination baking of cakes and found out that, cakes baked in MW-IR combination oven had similar color and firmness values with conventionally baked ones. Sakiyan et al. (2006) investigated the gelatinization of cakes baked in microwave and MW-IR combination oven and found out that combining infrared with microwaves increased gelatinization degree and made it comparable with the conventional cakes. Sakiyan et al. (2007) investigated the dielectric properties of different cake formulations during microwave and infrared-microwave combination baking and the effect of different formulations on physical properties of cakes baked with microwave and near infrared-microwave combinations. However, there seems to be a need for a broader research about the MW-IR combination baking of gluten free products and their quality during storage.

In order to understand the mechanism of MW-IR combination baking, the mechanisms of microwave and infrared heating should be reviewed separately.

1.3.1. Mechanism of Microwave Heating

Microwaves are electromagnetic waves within a frequency band of 300 MHz to 30 GHz. In the electromagnetic spectrum, they are embedded between radio and infrared waves (Regier and Schubert, 2005). Certain frequencies within this range of the electromagnetic spectrum are set aside by the International Telecommunications Union for industrial, scientific, medical and domestic use. These are at 2450 MHz, 915 MHz, and a few other frequencies according to geographical location (Meda et. al, 2005).

When microwaves impinge on a dielectric material, part of the energy is transmitted, part is reflected and the rest is absorbed by the material where it is dissipated as heat (Meda et. al, 2005). Microwaves are reflected from metal surfaces. The oven cavity is basically a metal box in which the waves bounce around. Microwaves are transmitted, that is, they pass through many materials including glass, ceramics, plastics, and paper. Some materials are only partially transparent to microwaves; that is, they absorb some energy. When microwaves are absorbed, their energy is converted to heat (Decareau, 1992).

The major food components (water, carbohydrates, lipids, proteins and salts (minerals)) interact differently with microwaves (Brewer, 2005). The major mechanisms of microwave heating of foods involve dipolar re-orientation and ionic conduction, which can be seen in Figure 1.4 (Adapted from Ozkoc, 2008). In foods, it is mostly the polar molecules that interact with microwaves to produce heat. Water is the most common polar molecule and it is a major component of most foods. The polar molecules like water, in the presence of a microwave electric field, attempt to line up with the field. Since the microwave field is reversing its polarity, millions of times each second, the water molecules only begins to move in one direction when they must reverse themselves and move to the other direction. In doing so, considerable kinetic energy is extracted from the microwave field and heating occurs. Ionic conduction is another important microwave heating mechanism. Ions being electrically charged are influenced by microwave fields that cause the ions in solution to flow first in one direction then in the opposite direction as the field is reversed (Decareau, 1992).

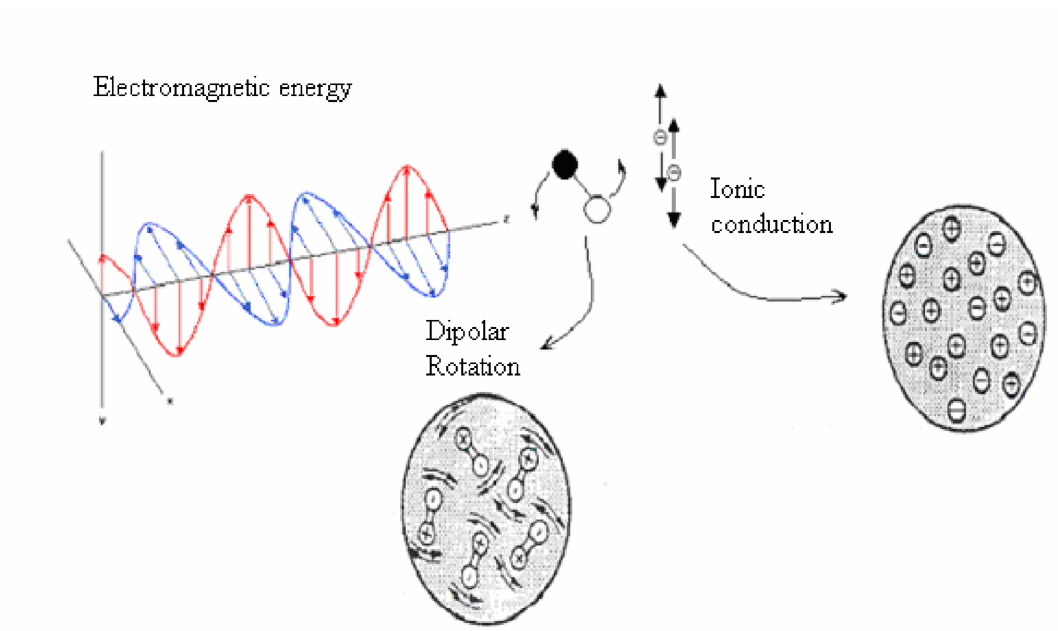


Figure 1.4 Schematic representations of dipolar rotation and ionic conduction mechanisms

The interaction of foods with microwaves is controlled by dielectric properties. Dielectric properties (dielectric constant, dielectric loss factor) are the physical properties of food that affect the behavior of the product during microwave heating, which may be helpful in understanding the microwave heating patterns of foods. The dielectric constant (ε') reflects the ability of a material to store electrical energy when in an electromagnetic field. The dielectric loss factor (ε") influences the conversion of electromagnetic energy into thermal energy (Tang, 2005). Information about the dielectric properties of food materials provides knowledge about the heating patterns during microwave and microwave-assisted heating (such as MW-IR combination heating) of foods.

The importance of dielectric properties of food materials increased as microwave processing and new combination processing technologies are adapted to be used in food industry. Dielectric properties provide assistance in developing products, processes and equipment with consistent and predictable properties.

In microwave heating the energy equation includes a heat generation term:

$$\frac{\partial T}{\partial t} = \alpha \nabla^2 T + \frac{Q}{\rho C_p} \qquad (1.1)$$

where, "T" is temperature, "t" is time, "α" is thermal diffusivity, "ρ" is density, "C_p" is specific heat of the material and "Q" is the rate of heat generated per unit volume of material per unit time. It represents the conversion of electromagnetic energy into heat. Its relationship to the electric field intensity (E) at that location can be derived from Maxwell's equation of electromagnetic waves as shown by Metaxas and Meredith (1983):

$$Q = 2\pi\varepsilon_0\varepsilon'' f E^2 \qquad (1.2)$$

where, "ε_0" is the dielectric constant of free space, "ε″" is the dielectric loss factor of the food; "f" is the frequency of oven (Meda et. al, 2005).

In microwave heating, time-temperature profiles within the product are caused by internal heat generation owing to the absorption of electrical energy from the microwave field and heat transfer by conduction, convection and evaporation. The surface temperature of a food heated by microwave energy is lower than the interior because of the lack of ambient heat in the microwave oven and the cooling effects of evaporation (Decareau, 1992). Wei et al. (1985a, 1985b) reported that, inside temperature of a porous media was found to be higher when heated by microwaves, on the other hand outside temperature was found to be higher when heated by convection owing to difference in heating mechanisms.

The advantages of microwave heating as compared to conventional heating can be summarized as less start-up time, faster heating, energy efficiency, space savings, precise process control, selective heating and final product with higher nutritive value (Decareau, 1992).

1.3.2. Problems in Microwave Baked Products

Microwave-baked products have some quality problems, such as having dense or gummy texture, crumb hardness and undesirable moisture gradient inside (Bell and Steinke, 1991). One of the reasons for these problems is that physicochemical changes and interactions of major ingredients, which would normally occur over a lengthy baking period in a conventional system, can not always be completed during the short baking period of a microwave system (Hegenbert, 1992). Specific interactions of each component in the formulation with microwave energy might be another reason (Sumnu, 2001). The short microwave baking time may also influence flavor development, that the flavor compounds may not be formed as under conventional baking conditions. Different flavor components may be completely volatilized at different rates and in different proportions in microwave heating than in conventional heating. Moreover, it was also found that different chemical reactions took place during microwave cooking when compared to conventional cooking, resulting in different flavor formation (Decareau, 1992).

The biggest difference between conventional and microwave ovens is the inability of the microwave ovens to induce browning. The cool ambient temperature inside a microwave oven causes surface cooling of microwave-baked products, which prevents formation of Maillard reaction products responsible for flavor and color (Sumnu and Sahin, 2005). The browning reactions in baked products are the result of heating reducing sugars with proteins or nitrogen-containing substances to form compounds like melanoidins. A relatively low food surface temperature and low surrounding temperatures in microwave baking do not enable the browning reactions to occur (Sumnu and Sahin, 2005). Sugars and sugar syrups undergo a series of complex reactions, called caramelization reactions, when there is no amino acid or protein like nitrogen containing compounds at the reaction medium. Caramelization reactions are non enzymatic browning reactions and they start by dehydration of reducing sugars at temperatures higher than 120ºC (Koksel, 2005). When the samples are heated in microwave oven for a longer period, they become dry and brittle but never brown. In order to eliminate the crustless products or unacceptable surface color, hybrid or multimedia ovens combining impingement and/or infrared with microwaves have been introduced (Keskin et al., 2004a; Geedipalli et al., 2008).

In microwave heating, relatively larger amounts of interior heating results in increased moisture vapor generation inside the food material, which creates significant interior pressure and concentration gradients. Moisture flows due to concentration and pressure gradients which results in higher rate of moisture losses during microwave heating (Datta, 1990). In the literature, it was found that, breads and cakes baked in microwave oven lost more moisture as compared to cakes baked in conventional oven (Sumnu et al., 1999; Zincirkiran et al., 2002; Seyhun, 2002; Keskin et al., 2004a; Demirekler et al., 2004: Demirkol, 2007).

When doughs of bakery products were produced by conventional formulations and then baked in microwave oven, unacceptable textures were obtained (Lorenz et al., 1973). It was identified that the exterior parts of the microwave-baked products are rubbery and tough and their interior parts are firm and difficult to chew (Mandala, 2005). Addition of fat and emulsifiers were shown to reduce the firmness of microwave baked breads (Ozmutlu et al., 2001a, 2001b). More amylose was shown to leach out during microwave baking of cakes as compared to conventional baking. This also explained why the initial texture of microwave baked cakes was firmer (Seyhun, 2002).

Breads baked in microwave oven stale faster compared to the ones baked in conventional ovens. This behavior is known as “Higo Effect” (Higo et al., 1983). The Higo Effect is the hypothesis that more amylose is leached out of starch granules during microwave heating of breads. This amylose was found to be more disoriented and contain less bound water than in conventionally baked bread. Upon cooling, the surrounding amylose molecules align and contribute to crumb firmness. The ability of amylose to realign into a more crystalline structure is better in microwave-heated bread than conventionally heated one, resulting in a harder texture (Sumnu, 2001).

In order to form microwave-baked products with comparable volume, texture and eating quality as those associated with conventionally prepared ones, new product development is required. Conventional formulations can be improved or new formulations can be designed by using some additives to solve the problem of toughness or firmness in microwave baked products. Processing conditions and heating mechanisms can also be adjusted to decrease the firmness in microwave-baked breads. Combination heating and addition of different food additives, such as gums may be alternative solutions to improve the quality of microwave baked products (Ozkoc, 2008).

1.3.3. Mechanism of Infrared Heating

One of the increasingly popular, but not yet common, methods of supplying heat to a product is infrared (IR) radiation. Materials are heated directly with IR radiation. IR lamps as well as hot rods and plates can be used as infrared sources (Mujumdar, 2007). IR radiation is the part of electromagnetic spectrum that is predominantly responsible for the heating effect of the sun. It is transmitted in a form of electromagnetic wave from the heat source, which does not need a medium for its propagation (Ranjan et al., 2002).

The relative position of infrared region of electromagnetic spectrum is in the wavelength range of 0.75 to 100µm. Infrared radiation is classified as the region of wavelengths between visible light and microwaves; moreover it is divided into three classes according to the wavelength i.e. near-infrared radiation (NIR): 0.75-3µm, middle-infrared radiation (MIR): 3-25µm and far-infrared radiation (FIR): 25-100µm (Meeso, 2008) (Figure 1.5).

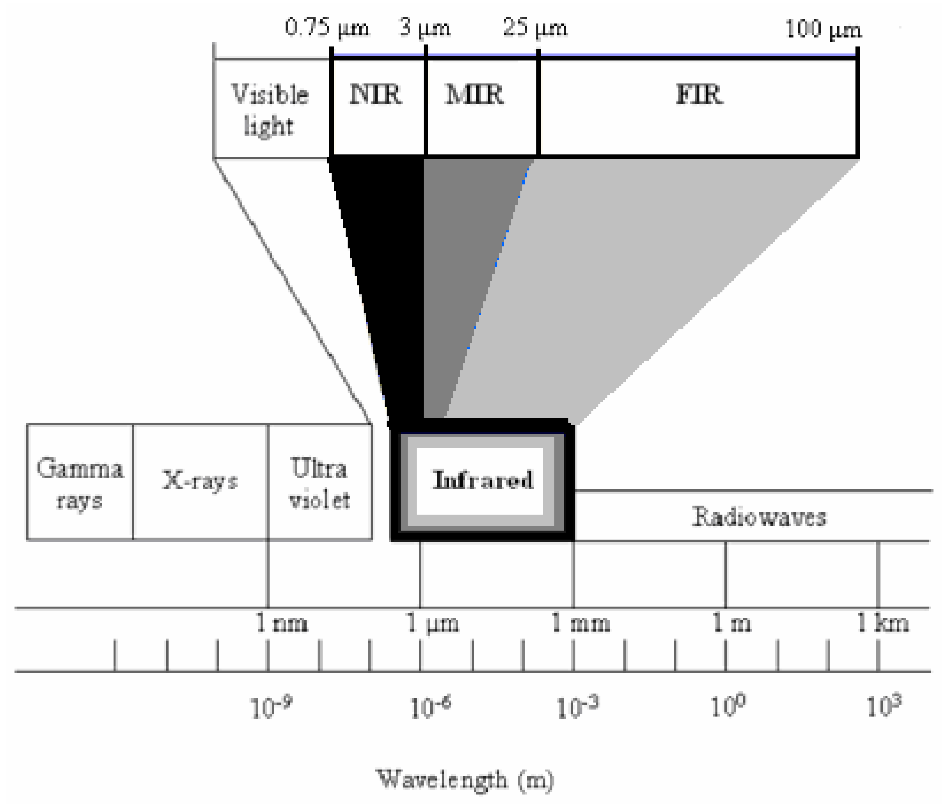


Figure 1.5 The electromagnetic spectrum (Adapted from Ozkoc, 2008)

IR heating is one of the heating methods that heat is transferred by radiation. The infrared source often has a high temperature (500-3000 °C). In IR heating, heat transfer by convection is also taking place and can not be ignored. As IR heating has poor penetration, it has an impact only on the surface of the body and heat transfer through the body proceeds by conduction or convection (Sepulveda and Barbosa-Canovas, 2003). The penetration depth of IR radiation determines how much the surface temperature increases or the level of surface moisture that builds up over time. Penetration depth of IR radiation can vary significantly for various food materials.

Use of different types of electromagnetic waves, for heating food and preservation of food has been reported by various researchers. Heating of foods by microwave heating has been examined in detail but by infrared heating to some extent (Datta and Ni, 2002). Temperature and moisture profiles for the foods heated by hot air assisted-microwave and infrared radiation were studied by Datta and Ni (2002), using a multiphase porous media transport model for energy and moisture in the food.

Some of the advantages of IR radiation are the versatility of IR heating, simplicity and compactness of the required equipment, easy accommodation of the IR heating with convective, conductive and microwave heating, fast transient response, reduced heating time, rapid processing, decreased probability of flavor loss, increased probability of preservation of vitamins in food products and also significant energy savings (Ranjan et al., 2002; Mujumdar, 2007)

Sumnu et al. (2005) and Keskin et al. (2004a) studied microwave, infrared and infrared-microwave combination baking of cakes and bread baking in halogen lamp–microwave combination oven, respectively. They found that, it was not desirable to bake cakes by using only IR heating since the product had a very thick crust. In addition, IR heating did not provide any advantage in reducing the baking time significantly. They concluded that it was possible to improve the quality of microwave baked cakes when IR heating was combined with microwave heating.

1.4. Baking of Cakes

During conventional baking, the product undergoes structural transformations such as starch gelatinization and volume increase. Water evaporation, crust formation and non-enzymatic browning also occur while heating takes place from the outer surface to inward. However, in MW-IR combination baking, microwave radiation interacts with molecules that are coupled to water (including dissolved solutes and ions) to produce heat, which then results in structural changes and water movement, and infrared radiation impacts only on the surface of the body and transfers heat through the body by conduction or convection. Interaction of microwaves with cake batter is highly dependent on the dielectric properties of the ingredients. Water is the most important dipole, but salt, fat and other ingredients also act as dielectric components. Thus, investigating the effects of different ingredients (e.g. starch, fat and proteins) on the microwave baking process is critical (Brewer, 2005).

In the literature, different additives and ingredients (such as sugars, fats, salts and hydrocolloids) have been used to modify the pasting properties of starch. Sugars raise gelatinization temperature and delay gelatinization of starch (Hoseney, 1986). Sugars achieve this by limiting water availability, lowering water activity and forming sugar bridges between starch chains (Kim and Walker, 1992a). Fats also retard starch gelatinization by delaying the transport of water into the starch granule through amylose-lipid complex formation (Kim and Walker, 1992b). Salts were added to rice starches in order to retard the retrogradation (Chang and Liu, 1991). Other compounds usually added to starch containing products are hydrocolloids such as gums due to their desirable effect on the acceptability of foods. Hydrocolloids have been widely used in food technology as additives in order to: (i) improve food texture, (ii) slow down the retrogradation of the starch, (iii) increase moisture retention, (iv) extend the overall quality of the product during storage, and also (v) as gluten-substitutes in the formation of gluten free breads since gums could act as polymeric substances that mimic the viscoelastic properties of gluten in bread doughs (Rojas et al., 1999)

High-quality cakes have various attributes, including high volume, uniform crumb structure, tenderness, shelf life and tolerance to staling. These attributes depend on the balanced formulas, aeration of cake batters, stability of fluid batters in the early stage of baking, and thermal-setting stage. The quality of a finished cake can be influenced by the addition of substances that affect these properties (Gomez et al., 2007).

It is hard to ensure the quality of gluten free products because of lack of gluten. The gluten free products must have quality characteristics similar to those produced by wheat flour. The removal of gluten from bakery products deteriorates quality and so the use of polymeric substances that mimic the viscoelastic properties of gluten is often required (Gallagher, 2003).

1.4.1. Changes in starch structure during baking

Starch granules are insoluble in water; however, their volumes slightly increase through absorption of water amounting up to 30% of their dry weight. These changes in volume and water absorption are reversible phenomena, but it becomes irreversible as temperature is increased, which result in significant variation in the granule structure. Starch polymers start vibrating vigorously, breaking intermolecular bonds and allowing their hydrogen bonding sites to connect more water molecules. The penetration of water leads to an increased separation of starch chains resulting in increase in randomness and decrease in number and size of crystalline regions. Continued heating causes complete loss of crystallinity. This process, gelatinization, can be defined as the transition of insoluble starch granules to a solution composed of individual molecules. Gelatinization involves: (1) starch hydration together with an increase of granule volume; (2) granule structure disruption; (3) heat absorption and (4) loss of granule crystallinity (León, 1997).

Starch granules are birefringent and show characteristic “Maltese cross” patterns when viewed by polarized light microscopy. When starch is heated in an aqueous environment, the starch granules begin to swell at a certain temperature, material is leached from the granules and structural order is irreversibly lost. There is a range of temperature, of the order of 10ºC, over which gelatinization takes place as measured by the loss of birefringence (Pomeranz, 1980). Microscopic examinations under polarized light (birefringence studies) are among the methods commonly used for studying effects of heat treatment on starch structure (Hoseney, 1986). Guler et al., (2002) used polarized light microscopy as a tool to investigate the effects of industrial pasta drying temperatures on starch properties and pasta quality.

Starch gelatinization is required for producing a baked good with desirable quality (Biliaderis, 1998). Several factors influence the gelatinization phenomenon, including the presence of water, sugar, fat, proteins, and hydrocolloids. The variation in the rates of moisture loss under microwave baking conditions can result in different degrees of starch gelatinization (Yin and Walker, 1995). This should be taken into consideration while developing microwave as well as MW-IR combination baked products.

Thermal analysis has been used extensively to study starch gelatinization (Hoseney, 1986). Of the thermo-analytical methods, differential scanning calorimetry (DSC) has been proven to be the most useful in providing basic information on starch gelatinization (Karim et al., 2000) and it has already been used for several decades. It measures the differential temperature or heat flow to or from a sample versus a reference material as a function of time, and can be used to monitor changes such as phase transitions (Verdonck et al., 1999). The gelatinization of starch can also be studied from its pasting behavior, usually by observing changes in viscosity using a variety of instruments including Rapid Visco^{TM} Analyzer (RVA) (Karim et al., 2000; Patel et al., 2005). RVA is a computer-integrated mixer viscometer developed to determine the viscous properties of cooked starch, grain, batter and other foods. It consists of a molded plastic stirring paddle where the apparent viscosity of samples is continuously measured under variable conditions of shear and temperature. Viscosity curves are used as fingerprints of the hydration and cooking characteristics of starchy materials. Changes in viscosity profiles give an idea about the effect of new processes on starch properties. In a typical RVA curve, there are some parameters measured from the pasting profile. These are: (i) peak viscosity (cP, maximum paste viscosity achieved in the heating stage of the profile), (ii) trough (cP, minimum paste viscosity achieved after holding at the maximum temperature), (iii) final viscosity (cP, the viscosity at the end of run), (iv) pasting temperature (ºC, the temperature at which starch granules begin to swell and gelatinize due to water uptake and defined as an increase of 25 cP over a period of 20 s), (v) peak time (s, the time at which peak viscosity was recorded), (vi) breakdown (cP, difference between peak viscosity and trough), (vii) setback (cP, difference between final viscosity and trough) (Juhász and Salgó, 2008). Early in the pasting test, the temperature is below the gelatinization temperature of the starch, and the viscosity is low. When the temperature rises above the gelatinization temperature, the starch granules begin to swell, and the viscosity increases on shearing. The temperature at the onset of the rise in viscosity is known as the pasting temperature. Pasting temperature provides an indication of the minimum temperature required to cook a given sample. When a sufficient number of granules become swollen, a rapid increase in viscosity occurs. Granules swell over a range of temperatures, indicating their heterogeneity of behavior. This range is reflected in the steepness of the initial rise in viscosity in the pasting curve. Peak viscosity occurs at the equilibrium point between swelling and polymer dissolving. Peak viscosity indicates the water binding capacity of the starch. It is often correlated with final product quality. As the temperature increases further, the granules rupture and the more soluble amylose leaches out into solution, followed in a slower rate by the amylopectin fraction. Granule rupture and subsequent polymer alignment due to the mechanical shear reduces the apparent viscosity of the paste (Koksel, 2005).

1.4.2. Quality of Cakes

High-quality cakes have various attributes, including high volume, uniform crumb structure, tenderness, adequate gelatinization degree, shelf life and tolerance to staling (Gomez et al., 2007). Every parameter that plays an important role on the acceptability of the cakes can be measured by various methods.

Texture parameters can be measured by both sensory evaluations and uniaxial compression methods. Ranking tests are hedonic measurements developed for sensory analysis and widely used to measure the food acceptability. The scale is a simple rating scale, used for many years to measure the acceptance of a food and to provide a benchmark number with which to compare products, to compare batches and to assess the level of acceptance of products in a competitive category. The panelists' task is easy: record the degree of liking, using the scale (Resurreccion, 2008).

Firmness of breads and cakes can be quantified by compressing the sample and measuring the force necessary to attain a predetermined penetration. Instrumental Texture Profile Analysis (TPA) has been widely adapted to the study of textural properties of bakery goods. In a TPA test, a sample of specific dimensions is compressed uniaxially (Karim et al., 2000). Some of the parameters of the TPA are hardness, springiness, cohesiveness, gumminess, fracturability and chewiness. Clerici et al. (2009) analyzed some of the texture features according to some texture profile parameter definitions. Hardness is the force necessary to attain a given deformation; springiness is rate at which a deformed material goes back to its non-deformed condition after the deforming force is removed; cohesiveness is how well the product withstands a second deformation relative to how it behaved under the first deformation; chewiness is the energy required for crunching a solid food to a state ready for swallowing; gumminess is the energy required to disintegrate a semisolid food to a state ready for swallowing and fracturability is the force with which a material fractures, a product of high degree of hardness and low degree of cohesiveness (Clerici et al. 2009).

1.5. Staling of Cakes

Staling refers to all physical and chemical changes that occur in baked products after baking. Staling makes the product less acceptable to a consumer. Although different approaches have been brought up to clarify the staling mechanism and to prevent it, the phenomenon of staling is still not completely understood. Although almost everyone agrees that starch retrogradation is the most important factor causing crumb firmness, the importance of other contributing factors and the means of retarding firming remain questionable (D'Appolonia and Morad, 1981). Staling has considerable economic importance for the baking industry since it limits the shelf life of baked products (Maarel et al., 2002).

During staling, changes occur both in the crumb and the crust. The increase in crumb firmness has probably been used to the largest extent by investigators following staling. Other changes, however, such as loss of flavor, decrease in water absorption capacity, amount of soluble starch and enzyme susceptibility of the starch, increase in starch crystallinity and opacity and the changes in x-ray diffraction patterns have also been used (D'Appolonia and Morad, 1981).

Strategies to extend freshness of baked products can be summarized as formulation modifications, variation of production parameters and use of various processing methods (Zobel and Kulp, 1996). The mostly used strategy in retarding the staling of baked products is modification of formulation. Ingredients such as emulsifiers, sugars, shortenings, enzymes and hydrocolloids have different effects on bread staling. But since cake is a complex medium and all the ingredients interact with each other, it is difficult to estimate their specific effects on staling.

1.5.1. Mechanisms of Staling

Staling is a very complex process that cannot be explained by a single effect. It involves amylopectin retrogradation, reorganization of polymers within the amorphous region, loss of moisture content, distribution of water between the amorphous and crystalline zones (Hoseney, 1986). Changes occur in both crumb and crust (D'Appolonia and Morad, 1981). Stampfli and Nerste (1995) emphasized that consumers associate staling with some typical sensorial changes in bread such as loss of flavor, loss of crispness in the crust, increased crumbliness and crumb firmness. Characteristics of the crumb that have been used as bases to determine the degree of staling are changes in taste and aroma, increased hardness, increased opacity, increased crumbliness, increased starch crystallinity, decreased absorptive capacity, decreased susceptibility to α-amylase, and decreased soluble starch content (Hoseney, 1986).

In order to understand staling mechanism of products baked in MW-IR combination oven, first of all, it is necessary to understand the staling mechanism of products baked in conventional oven. There are mainly two general mechanisms of staling; one is the redistribution of moisture and the other one is the starch retrogradation.

1.5.1.1. Redistribution of moisture

Although starch retrogradation has been emphasized as the key factor in crumb firming, one feature which appears puzzling is that starch is a dispersed phase and it would be expected that the continuous phase (gluten) is the important one in determining the rheological properties of a material. This has led to speculation about moisture redistribution between components (especially starch and gluten) as an explanation for crumb firming (Hoseney, 1986). In gluten free products, there is no gluten and the continuous phase is formed by hydrocolloids. Hence, redistribution of moisture between starch and hydrocolloids might influence staling. It might be worth investigating whether redistribution of moisture between starch and hydrocolloids plays a significant role in staling of gluten free bakery products.

1.5.1.2. Starch Retrogradation

The reason of emphasizing retrogradation phenomenon is due to its effects on quality, acceptability and shelf-life of starch-containing foods (Biliaderis, 1991). Gelatinization process which occur during baking in the oven, cause some of the starch (mainly amylose) to be expelled from the granules; the granules swell and distort, thus forming contacts and, in some cases, partial coalescence with each other. Strong evidence has accumulated showing that changes in the starch are the major factors causing bread staling.

When gelatinized starch is kept below the gelatinization temperature, amylose molecules, reassociate into a more orderly form constituting new hydrogen bonds, which is referred to as "retrogradation" (Zallie, 1988; McWilliams, 1989). Starch retrogradation is divided in two kinetically different processes: first the amylose fraction undergoes rapid gelation and second amylopectin short chains recrystallize at a much lower rate compared with amylose (León et al., 1997). Whether the fraction of starch that contributes to bread firming is amylose or amylopectin has also been debated. Schoch and French (1947) showed that the water-soluble material that could be leached from bread crumb at 30 °C was predominantly amylopectin. They hypothesized that progressive spontaneous aggregation of amylopectin molecules was responsible for bread firming. The important role of amylopectin in starch retrogradation was confirmed by calorimetry. However, Hoseney (1986) have pointed out that stale bread must be heated to about 100 ºC before its compressibility approached that of fresh bread. Since retrograded amylopectin should have melted by the time the temperature reached 60 ºC, retrogradation of amylopectin cannot be the only factor affecting firming. It was concluded that amylopectin retrogradation was part of the staling process, but it was not solely responsible for the observed changes in texture.

Starch retrogradation is mostly affected by two factors: temperature and moisture content of the baked product (Stauffer, 2000). Retrogradation is negatively correlated with temperature that it accelerates as temperature decreases. Studies showed that starch retrogradation slowed down when the moisture content of the starch gel was high (Stauffer, 2000).

1.5.2 Methods for Measuring Degree of Staling

Probably because of the mystery that still surrounds the staling process, a variety of techniques have been employed to measure staling and/or to investigate the changes that accompany it. Staling in bakery products falls into two categories: crust staling and crumb staling. Crust staling is generally caused by moisture transfer from the crumb to the crust, resulting in a soft, leathery texture and is generally less objectionable than crumb staling. Crumb staling is more complex, more important, and less understood (Gray and BeMiller, 2003). It is obvious that using only one method will not completely measure or describe the degree of staling as noticed by the consumer (Sidhu et al. 1997). Many of the methods used to measure bread staling are based on determination of the extent of starch retrogradation.

Thermal analysis has been used extensively to study starch retrogradation as well as bread staling (Pomeranz 1980; Hoseney, 1986; León et al., 1997; Verdonck et al., 1999; Kohyama et al., 2004). Of the thermo-analytical methods, DSC has proven to be the most useful in providing basic information on starch retrogradation (Karim et al., 2000). When aged samples are heated in a DSC pan, an endotherm is observed as reordered amylopectin reaches its melting temperature, and the enthalpy change associated with this transition can be measured.

Changes in texture also accompany the bread staling phenomenon and can be measured by both sensory evaluations and uniaxial compression methods (Resurreccion, 2008). Instrumental TPA has been widely adapted to the study of starch retrogradation in actual food and model starch gel systems. As the staling increases, the force required to compress the product increases, therefore, a relationship between firmness and storage time may be developed (Gil et al., 1999).

The tendency of a starch to retrograde can also be studied from its pasting behavior, usually by observing changes in viscosity using a variety of instruments including RVA (Karim et al., 2000; Patel et al., 2005). Among all the RVA profile parameters, one of the most important one is the setback value. It is an increase in viscosity, observed owing to reordering of amylose during the cooling stage of the test. In the literature, setback is related with the retrogradation of the amylose chains (Lent and Grant, 2001; Collar, 2003; Sopade et al., 2006). D'Appolonia and Morad (1981) demonstrated that viscosity changes resembled firming curves and other measurements that have been related to starch crystallization.

The understanding of rice starch behavior in terms of gelatinization and retrogradation is a promising subject. In the literature there are various studies on this subject. Wu et al. (2008) investigated the effect of tea polyphenols on the retrogradation of rice starch. Viturawong et al. (2008) studied the gelatinization and rheological properties of rice starch/xanthan mixtures. Zhong et al. (2009) studied the effect of rice variety and starch isolation method on the pasting and rheological properties of rice starch pastes. Tan et al. (2009) studied the changes in gelatinization and rheological characteristics of japonica rice starch induced by pressure/heat combinations.

1.6. Objectives of the study

Products containing gluten can not be consumed by people suffering from gluten intolerance (celiac disease). Upon eating gluten, these people encounter damage to their small intestine. In order to overcome the problems that gluten intolerant people are facing, there are ongoing studies to create diverse gluten free products with fair prices. The use of different technologies has recently been growing for developing new products with higher quality and reasonable price. MW-IR combination technology is a novel technology that combines the time saving advantage of microwave heating with the browning and crisping advantages of infrared heating. The studies about gluten free cakes baked in MW-IR combination oven are limited in the literature. Turabi et al. (2008) determined the effects of different gums on rheological properties of batter and quality of cakes baked in MW-IR combination oven. However, the effects of different gum concentrations on quality and the effect of different gums on gelatinization degrees and staling of gluten free cakes have not been studied yet.

The main objective of this study was to determine the effects of different gums and gum concentrations on the quality and staling of gluten free cake formulations to be baked in MW-IR combination oven. The quality and the staling of these cakes were compared with the ones baked in conventional oven. Cakes were formulated using rice flour which is gluten free. Since gluten is responsible for elastic properties of batter, it is necessary to use additional ingredients in rice flour containing cakes. For this purpose, different types of hydrocolloids, namely xanthan and guar gum (at different concentrations) and their blend were used. As quality characteristics, moisture loss, specific volume, hardness, color and taste of the cakes were determined. Furthermore, the gelatinization degrees and starch pasting properties of the cakes baked in different ovens were compared. In addition to these, staling of gluten free cakes containing different gums was studied. As staling parameters, moisture loss, hardness, retrogradation enthalpy and setback viscosity of the cakes baked in MW-IR combination oven and conventional oven were determined during storage.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

For cake batter preparation, rice flour having 10% moisture, 6% protein (N×5.95), 0.6% ash (Knorr-Capamarka, Istanbul, Turkey), sugar (sucrose), salt and baking powder (Bagdat Baharat, Ankara, Turkey) and shortening (Becel, Unilever, Turkey) containing vegetable oil, water, non-fat pasteurized milk, emulsifier blend (vegetable mono/digliserides, soy lecithin), salt, lactic acid, potassium sorbate, vitamins (E, B6, Folic acid, A, D and B12), butter aroma and color additive (beta carotene), were bought from local markets. Egg white powder was obtained from Ulker Biscuit Industry Co. Inc. (Ankara, Turkey). Xanthan gum (*Xanthomonas campestris*) and guar gum were obtained from Sigma-Aldrich (Steinheim, Germany).

2.2 Methods

2.2.1 Batter Preparation

A cake batter recipe containing 100% rice flour, 100% sugar, 25% shortening, 9% egg white powder, 3% salt and 5% baking powder (all percentages are given on flour weight basis) was used in the experiments. The amount of water added to the batter was 27% of the overall formulation. The gums (xanthan gum, guar gum) were added to the batter formulation at 0.3, 0.6, 1.0% concentrations (on flour weight basis). Xanthan–guar gum blend was prepared by mixing these gums in equal proportions (0.5% xanthan gum + 0.5% guar gum on flour weight basis). The cake containing no gum was used as control. During preparation of the cake, firstly, dry ingredients (rice flour, baking powder, salt and gum) were mixed thoroughly. In a separate cup, sugar and egg white powder were mixed, and then melted shortening was added and mixed for 1 min at 85 rpm by using a mixer (Kitchen Aid, 5K45SS, USA). Then, dry ingredient mix and water were added simultaneously to this mixture and mixed; first for 2 min at 85 rpm, then for 1 min at 140 rpm and finally for 2 min at 85 rpm (Turabi et al., 2008).

2.2.2 Baking

Samples were baked in two types of ovens, namely; conventional oven and MW-IR combination oven.

2.2.2.1 Conventional Baking

Conventional baking was performed in a commercial electrical oven (Arcelik, Istanbul, Turkey). The batter samples were baked at 175°C for 30 minutes which was determined as the optimum baking condition for conventional baking according to the previous literature (Turabi et al., 2008). One batter sample of 100 g initially, was baked at a time.

2.2.2.2 MW-IR Combination Baking

MW-IR combination baking was performed in MW-IR combination oven (Advantium oven™, General Electric Company, Louisville, KY, USA). Two halogen lamps, one at the top and one at the bottom were operated at the same power. The maximum power of microwave determined by IMPI-2L test (Buffler, 1993) was 682 W. Cake samples of 100 g were baked at 70% upper and lower halogen lamp power and 40% microwave power for 7.5 minutes which was determined according to the previous literature (Turabi et al., 2008). One batter sample of 100 g initially, was baked at a time.

Preliminary experiments showed that cakes baked in the MW-IR combination oven lost significant amount of moisture. Therefore, two beakers, each of them containing 400ml water, were placed at the back corners of the oven to provide humidity during baking.

2.2.3 Storage

After baking, cakes were allowed to cool down for 1 hour; then placed in plastic bags and kept at 22±2 °C for different period of storage times (0, 24, 48, 72, 96 and 120 hours).

2.2.4. Analysis of Cakes

In fresh cake samples; weight loss, moisture content, specific volume, texture profile, crust color, birefringence, Rapid Visco Analyzer (RVA) and Differential Scanning Calorimeter (DSC) analyses were performed.

For cakes stored for different period of times, weight loss, texture profile, RVA and DSC analysis were done.

2.2.4.1 Weight Loss

Percent weight loss (WL %) of cakes during baking was calculated by using the weight of cake sample at any time (W_{cake}) and weight of cake batter (W_{batter});

$$WL(\%) = \left[\frac{W_{batter} - W_{cake}}{W_{batter}} \right] \times 100$$

where, W denotes weight (g).

2.2.4.2. Moisture Content

In order to prepare the samples for RVA and DSC analysis, the moisture contents of the cake samples which were immediately frozen (-80ºC) and then freeze dried (Christ, Alpha 1-2 LD plus, Germany) for 48 hours, were determined. The moisture content of the cake samples were determined according to the AACC 44-19 (2000) method. The cakes were ground in a coffee grinder (Moulinex, Super Junior S, A 505 2H F, France) and sieved through a 212-μm screen. Samples (2 g ± 1 mg) were weighed into previously dried and cooled aluminum moisture dishes. With covers removed, the samples are dried for 2 hours at 135ºC. Covers are placed on dishes and transferred to desiccators to cool. The dishes are weighed and the loss in weight is calculated as moisture. The analyses were performed in triplicates.

2.2.4.3. Specific Volume

Specific volume of the cakes was determined by the rape seed displacement method (AACC, 1988).

The volume of the cakes was calculated by measuring the weight of the container containing cake sample and completely filled with rape seeds and using density of the seeds;

$$W_{seeds} = W_{total} - W_{cake} - W_{container}$$

$$V_{seeds} = W_{seeds} / \rho_{seeds}$$

$$V_{cake} = V_{container} - V_{seeds}$$

where, W represents weight (g), V represents volume (cm^3), and ρ represents density (g/cm^3).

The specific volume was calculated by dividing the volume of the cake by its weight:

$$SV_{cake} = \frac{V_{cake}}{W_{cake}}$$

where, SV is the specific volume (cm^3/g).

2.2.4.4 Texture Profile Analysis (TPA)

Crumb hardness (N) of cake samples was measured using a universal testing machine (Lloyd Instruments LR 30K, UK) after the cake samples had been cooled for 1 hour. Samples with cubic shapes having dimensions of 25*25*25mm were cut from the central regions of the cakes and were compressed to 25% of their original thickness at a speed of 55 mm/min. A cylindrical probe with a diameter of 10 mm and a load cell of 50 N were used. In addition, springiness (mm), chewiness (N*mm) and gumminess (N) were also determined. The graphical representation of texture profile analysis is represented in Figure 2.1 (Adapted from Ozkoc, 2008).

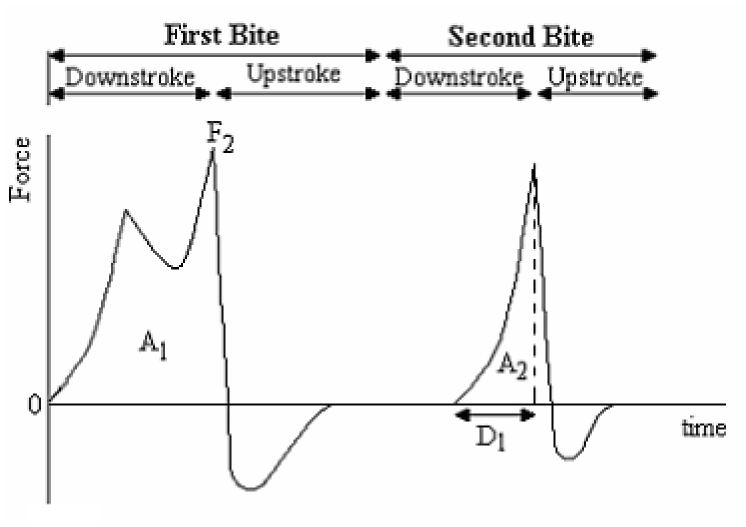


Figure 2.1 Graphical representation of Texture Profile Analysis (Adapted from Ozkoc, 2008)

Texture profile parameters were determined from:

Hardness: F2

Springiness: D1

Chewiness: hardness x cohesiveness x springiness: F2 x (A2/A1) x D1

Gumminess: hardness x cohesiveness: F2 x (A2/A1)

2.2.4.5 Color

The surface color of cakes and the color of cake batter were measured by using Minolta Color Reader (Minolta CR-10, Osaka, Japan). CIE L^*, a^*, b^* color scale was used for color measurements. The $L*$ value indicates lightness/darkness, the $a*$ value represents the degree of redness/greenness and the $b*$ value represents the degree of blueness/yellowness. Total color difference (ΔE) was calculated from the following equation:

$$\Delta E = [(L* - L_{ref}*)^2 + (a* - a_{ref}*)^2 + (b* - b_{ref}*)^2]^{1/2}$$

where, $L_{ref}*$, $a_{ref}*$, $b_{ref}*$ represents the L^*, a^*, b^* values of the cake batter ($L_{ref}* = 67.8$, $a_{ref}* = 2.7$, $b_{ref}* = 31.9$).

2.2.4.6 Birefringence Studies

Birefringence studies were evaluated in water–glycerol (50:50) suspensions of the rice starch and ground cake samples according to the method of Koksel et al. (1993). Bright-field and polarized-light microscopic examinations were made using a microscope (Leica DM LP, Leica Microsystems, Germany). 50 x magnification was used during the examination.

2.2.4.7. Rapid Visco Analyzer (RVA) Analysis

Rapid Visco Analyzer (RVA) (Newport Scientific PTY. Ltd., Warriewood, NSW, Australia) was used to study pasting properties of starch in different cake types. Before RVA analysis, cake samples were immediately frozen (-80ºC) and then freeze dried (Christ, Alpha 1-2 LD plus, Germany) for 48 hours. Then the dry cake samples were defatted by soxhlet extraction with n-hexane for 6 hours. The defatted samples were ground in a coffee grinder (Moulinex, Super Junior S, A 505 2H F, France) and sieved through a 212-μm screen. The RVA pasting curve was obtained by using a 23 minute standard test. The heating and cooling cycles were programmed in the following manner. Initially, the samples were held at 50ºC for 1 min, heated to 95ºC over 7.5 min; hold at 95ºC for 5 min; cooled to 50ºC over 7.5 min and hold at 50ºC for 2 min. For the fresh cakes, the peak viscosity, i.e. the maximum viscosity during pasting, breakdown viscosity, i.e. the difference between the peak viscosity and the minimum viscosity during pasting, setback viscosity, i.e. the difference between the maximum viscosity during cooling and the minimum viscosity during pasting, final viscosity, i.e. the viscosity at the end of the RVA run (Chaisawang and Suphantharika, 2006), were determined from the RVA plots by using the analysis software supplied with the instrument (Termocline for Windows, Version 2.0.).

For the staling part of the study, after the storage periods, the peak viscosity and setback viscosity were determined.

Percent setback values were computed according to the following equation:

$$Setback(\%) = \frac{[Setback(120hr) - Setback(0hr)]}{Setback(0hr)}$$

2.2.4.8. Differential Scanning Calorimetry (DSC) Analysis

The dried cake samples were ground in a coffee grinder (Moulinex, Super Junior S, A 505 2H F, France) and sieved through a 212-μm screen. After that, dry cake samples were weighed (3 ± 1 mg) into DSC pans. The samples were wetted by adding water (ratio dry sample:water = 1:3) with a micro-syringe. The DSC pans were sealed and reweighed for the determination of the water content of the sample. The pans were hermetically sealed and allowed to equilibrate at a cold storage room (5±2ºC) for 24 h prior to analysis. The samples were placed in the standard hermetically sealed DSC pans and put into the DSC cell with an empty pan as a reference. The DSC cell was heated at a rate of 5 °C/min from 10 °C to 100 °C. Gelatinization and other phase transition temperatures were recorded on a Q2000 Model Differential Scanning Calorimeter (DSC-TA Instruments, USA).

Enthalpies were computed automatically using the analysis software supplied with the instrument. Two endothermic peaks were obtained from the DSC curves. The area of the first endothermic peak, which was at a lower temperature, was used to calculate the retrogradation enthalpy of the cake samples. The area of the second endothermic peak obtained from the DSC curve was referred as the gelatinization enthalpy. The endothermic peak obtained by heating of cake batter in DSC was considered as the enthalpy required for complete gelatinization of the starch in the sample. Then, the gelatinization degree in the processed samples was calculated by using the following equation (Ndife et al., 1998):

$$\text{Gelatinization degree (\%)} = \left(1 - \frac{\Delta H_{PS}}{\Delta H_{CB}}\right) \times 100$$

where ΔH_{PS} is the enthalpy of processed sample and ΔH_{CB} is the enthalpy of cake batter.

2.2.4.9. Sensory Analysis

Sensory analyses of the fresh cakes were performed by a hedonic ranking test by untrained panelists (Resurreccion, 2008). A 5-point ranking scale was used by doing modifications such as simplifying the 9-point ranking scale. The ranking scale categories were:

- Like extremely (=5)
- Like moderately (=4)
- Neither like or dislike (=3)
- Dislike moderately (=2)
- Dislike extremely (=1)

Two different cake formulations, namely; control cake and the cake containing gum blend baked in two different ovens were used in the sensory analysis. Two different sensory parameters, which are texture and taste, were used in the analysis. In the analysis, the cakes containing the gum blend were chosen in order to evaluate the acceptability of the cakes that had the best results in terms of the quality parameters (weight loss, specific volume and hardness). Cakes containing no gum (control cakes) were used for comparison.

2.2.4.10. Gluten Analysis

The gluten contamination analysis was performed by a gluten assay kit (Biokits gluten assay kit, Tepnel Research Products and Services, Stamford, ABD). The protocol was designed to detect very low levels of gluten contamination with a quantification range of 3-50 ppm according to the Association of Analytical Communities (AOAC 991.19 Method).

Monoclonal antibodies used in this enzyme-linked immunosorbent assay (ELISA) bind to proteins from celiac-toxic cereals (wheat, rye, triticale, barley) but not non toxic cereals (rice, maize) Advantage of particular antibodies used in test is that they bind to proteins that are not denatured by heat during processing or cooking of foods. In method, test portion is extracted with aqueous ethanol and centrifuged. Gluten is quantified in supernate by 2-step sandwich method of ELISA. First, gluten analyte (antigen) is incubated with monoclonal antibody immobilized onto the micro well strip to form gluten antigen–antibody complex, which is then incubated with enzyme-labeled antibody. Gluten in product forms a complex sandwiched between antibody attached to well and antibody labeled with enzyme. Amount of analyte is determined by adding substrate. Washing steps incorporated after each interaction stage remove any non immobilized species. Response is compared with that observed with gliadin standard, starches, and suitable blanks.

For analysis, food samples were extracted with an ethanol solution (Ethanol–water (40%, v/v)) and the extracts were diluted in a buffer (27.3 g anhydrous Na_2HPO_4, 9.0 g $NaH_2PO_4 \times 2H_2O$, 45 g NaCl, and 0.5 g thimerosal as preservative per liter), prior to addition to micro wells (monoclonal antibodies to heat-stable gluten components are coated in 50mM sodium carbonate buffer, pH 9.6) coated with monoclonal antibodies to omega gliadin. With increased concentrations of gluten in the diluted extract, more of the gliadin present will bind to antibody attached to the well. After allowing this reaction to proceed, unbound material was removed by washing. The amount of gliadin remaining bound to the antibody was determined by the reaction by a peroxidase-linked monoclonal antibody to gliadin. After incubation, excess conjugate was removed by washing. Bound peroxidase activity was determined by adding a fixed amount of TMB (tetramethylbenzidine) substrate, which developed a blue color in the presence of peroxidase. Color development was proportional to the gliadin concentration of the extract. The amount of gluten can be determined using a calibration curve derived from known standards and converting gliadin levels in the extract to sample gluten content. A typical absorbance curve is presented in Figure 2.2 (AOAC, 1995)

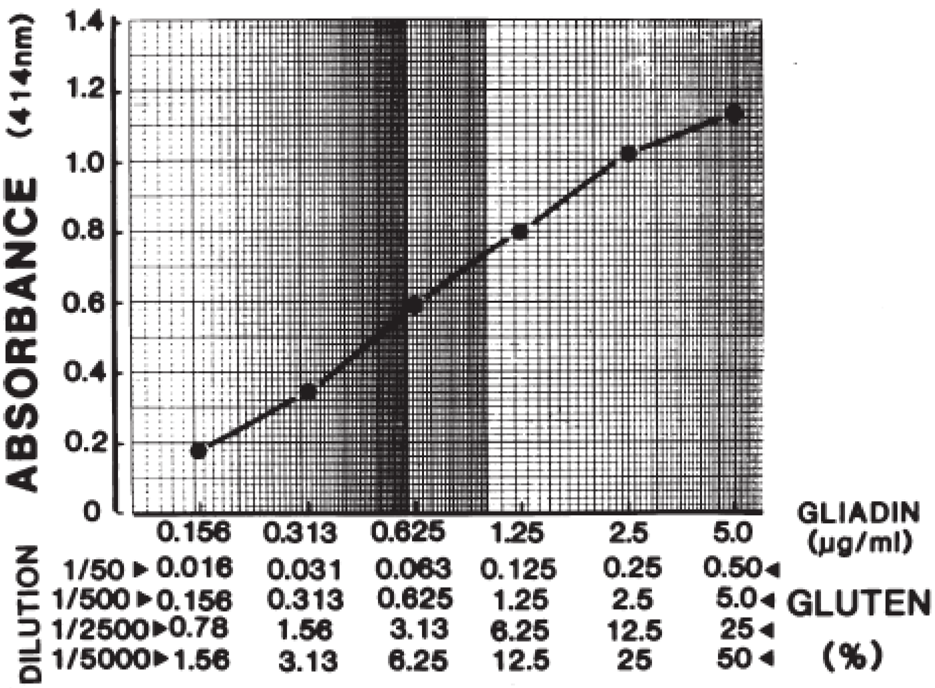


Figure 2.2 A typical absorbance curve for gluten contamination analysis (AOAC, 1995)

2.2.5. Statistical Analysis

Analysis of variance (ANOVA) was performed to determine whether there was a statistically significant effect of storage periods, gum types and concentrations or oven types ($p \leq 0.05$). Variable means were compared by Duncan's test by using SPSS statistics program (SPSS 14-Evaluation pack for Windows, 2001).

CHAPTER 3

RESULTS AND DISCUSSION

In the first part of the study, effects of different gums (xanthan gum and guar gum) and gum concentrations (0.3, 0.6, and 1.0%) on the quality parameters (weight loss, specific volume, hardness, texture profile, crust color and sensory properties) and the pasting properties (RVA profiles) of cakes baked in MW-IR combination oven were investigated. In addition, the gelatinization degrees of the cakes were determined. For comparison, the cakes having the same formulation and baked in conventional oven were used.

In the second part of the study, staling of the cakes baked in MW-IR combination ovens was investigated by different methods (weight loss, hardness, DSC, RVA) during storage. For comparison, the cakes having the same formulation but baked in conventional oven were used.

Furthermore, cake samples and ingredients of the cake formulation were tested for gluten contamination.

3.1 Effects of Different Gums and Gum Concentrations on the Quality Parameters of Cakes Baked in Different Ovens

In the present study, different concentrations of xanthan gum and guar gum were chosen for the development of the cake formulation. This decision was based on the results by Turabi et al. (2008) who studied the rheological properties of cake batters and quality of rice cakes formulated with different gums at 1.0% concentration and obtained the best results (in terms of emulsion stability and apparent viscosity of cake batter, texture, volume and porosity and collapse of the cakes in the oven) for xanthan gum and guar gum. In addition, in that study a synergistic interaction between xanthan and guar gum was observed resulting in higher apparent viscosity of cake batters as compared to other gums. Moreover, it is known that xanthan and guar gums can sufficiently function at very low levels to be cost-effective. Therefore, in the first part of the study, xanthan and guar gums were added to the cake formulation at 0.3, 0.6 and 1.0% concentrations. In addition to these concentrations, a combination of the two gums at a concentration of 0.5% xanthan gum and 0.5% guar gum was used. The effects of different gums and gum concentrations on weight loss, specific volume, hardness, texture profile parameters, crust colors and sensory properties of cakes were examined.

3.1.1. Effects of Different Gums and Gum Concentrations on Weight Loss of Cakes Baked in Different Ovens

The effects of xanthan gum and guar gum at different concentrations and the combination of the two gums on weight losses of the cakes baked in different ovens are presented in Figure 3.1. It was found that the cakes baked in MW-IR combination oven lost more weight than the ones baked in conventional oven (Table A.1). This may be due to the difference in heating mechanisms of the two baking methods. MW-IR combination heating combines microwave and IR heating. In microwave heating, relatively larger amounts of interior heating results in increased moisture vapor generation inside the food material, which creates significant interior pressure and concentration gradients and results in high moisture losses (Datta, 1990). Sumnu et al. (2005) studied the microwave, infrared and MW-IR combination baking of cakes and concluded that, weight loss of cakes baked in conventional oven was lower than that of the cakes baked using microwaves and at longer baking times in MW-IR combination oven. The high moisture loss in microwave baked products has also been reported by other researchers (Sumnu et al., 1999; Seyhun et al., 2003). Since MW-IR baking combines microwave and IR heating and the main mechanism in MW-IR heating is the microwave heating, higher moisture loss values were expected for cakes baked in MW-IR combination oven.

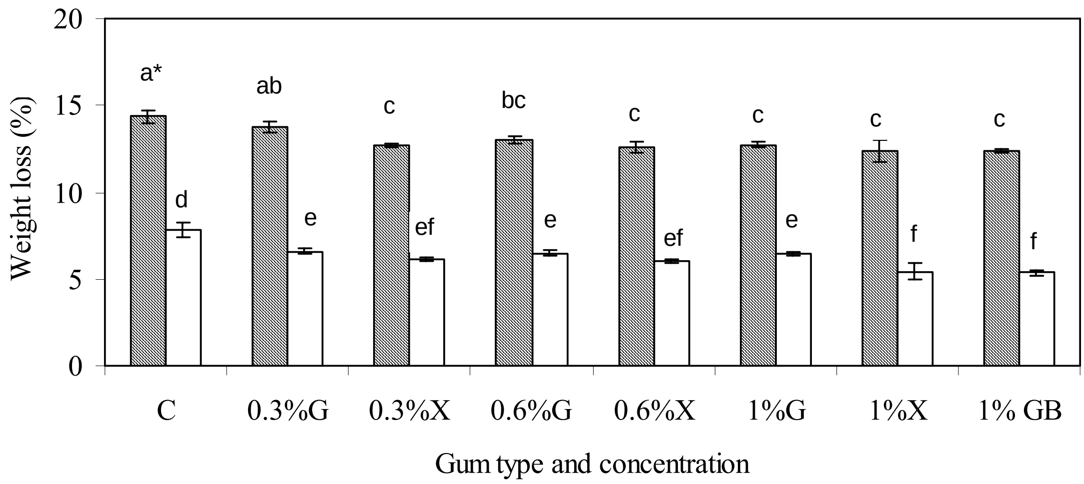


Figure 3.1 The effect of gum types and concentrations on the weight losses of cakes baked in MW-IR combination oven and conventional oven ((▧): MW-IR combination oven, (□): Conventional oven, C: Control cake, G: Guar gum containing cake, X: Xanthan gum containing cake, GB: Gum blend containing cake) (* means columns with different letters are significantly different, $p \leq 0.05$)

If the cakes baked in MW-IR combination oven are considered, the control cake and the cake containing 0.3% guar gum had significantly higher weight loss than the cakes containing xanthan and gum blend (Figure 3.1). However; as guar gum concentration was increased from 0.3 to 1.0%, weight loss of cakes decreased significantly ($p<0.05$). This may be due to the water binding capacities of gums. The effect of xanthan gum concentration on weight loss of cakes was not found to be statistically significant.

If the cakes baked in conventional oven are considered, the control cake had the highest weight loss (Figure 3.1). Since the control cake did not contain any gum to bind water, the control cake was expected to have the highest weight loss value. The effect of guar gum and xanthan gum concentrations on weight loss of cakes was not found to be statistically significant.

If cakes baked in both types of ovens were considered, the addition of xanthan gum at all concentrations showed a significant reduction in weight loss values when compared with the control cake. However; among the xanthan gum containing cakes, the concentration did not have a statistically significant effect on weight loss values. The addition of guar gum at concentrations higher than 0.3% showed a significant reduction in weight loss values when compared with the control cake, for cakes baked in baked in both types of ovens. Gomez et al. (2007) investigated the functionality of different hydrocolloids on the quality and shelf life of yellow layer cakes and found that cakes containing hydrocolloids always showed lower moisture losses than the control cakes during baking. They also explained their results by the ability of hydrocolloids to increase moisture retention.

3.1.2. Effects of Different Gums and Gum Concentrations on Specific Volume of Cakes Baked in Different Ovens

The effects of gum types and concentrations on specific volumes of cakes baked in MW-IR combination oven and conventional oven are presented in Figure 3.2. When the two baking methods were compared, the specific volumes of the cakes containing 0.3% xanthan gum and the gum blend and baked in MW-IR combination oven were significantly higher than those of the cakes having the same formulation baked in conventional oven ($p<0.05$) (Table A.2). There was no statistically significant difference between the other cakes having the same formulation but baked in two different ovens. Therefore, it can be concluded that, the cakes baked in MW-IR combination oven had comparable or significantly higher specific volume values than the cakes baked in conventional oven depending on the formulation. For both types of ovens, the xanthan gum containing cakes resulted in higher specific volumes than the guar gum containing cakes at concentrations greater than 0.3%. Lazaridou et al. (2007) who studied the effects of hydrocolloids on gluten free breads found that guar gum addition yielded a product with lower volume than that of the control samples. On the other hand, xanthan gum addition resulted in high specific volume and porosity than that of the control cake.

In MW-IR combination oven, the best result was obtained when gum blend was used in the cake formulation (Figure 3.2). This might be explained by synergistic effect of using xanthan gum and guar gum together. Guar gum interacts synergistically with xanthan gum and the synergistic effect is explained by different models (Schorsh et al., 1997; Sworn, 2000; Gurkin, 2000, Ward and Andon, 2002). There was no significant difference between the control cake, guar gum containing cakes and 0.3, 0.6% xanthan containing cakes for cakes baked in MW-IR combination oven.

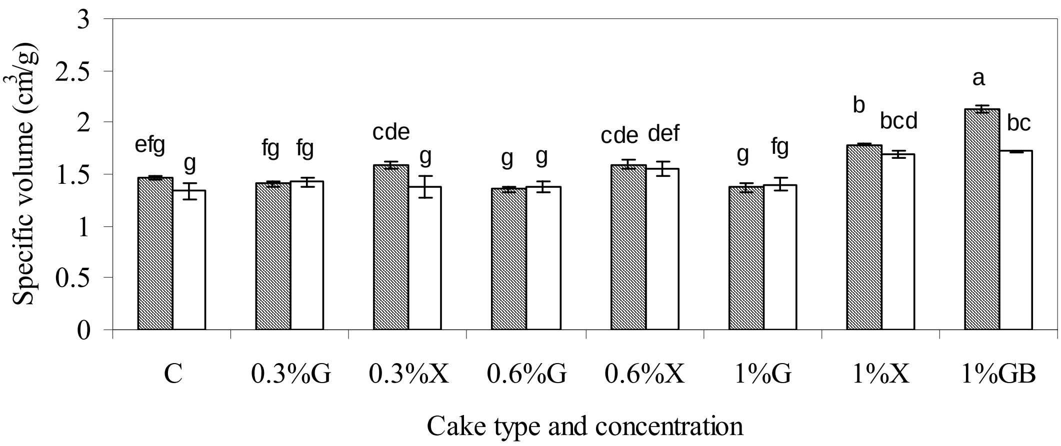


Figure 3.2 The effects of gum types and concentrations on the specific volume of cakes baked in MW-IR combination oven and conventional oven. ((▨): MW-IR combination oven, (□): Conventional oven)

When the cakes baked in conventional oven were compared, similar results with MW-IR combination oven were obtained (Figure 3.2). The higher specific volumes were obtained for 1.0% xanthan gum and gum blend containing cakes. Similar results were reported by various researchers (Gomez et al., 2007; Mandala, 2005). Gomez et al. (2007) who studied the functionality of different hydrocolloids on the quality of yellow layer cakes found that xanthan gum containing cakes had the highest volume. Influence of xanthan gum on cake volumes can be explained by the increase observed in batter viscosity that slowed down the rate of gas diffusion and allowed water retention during the early stages of baking (Gomez et al., 2007). Mandala (2005) studied the physical properties of fresh and frozen stored, microwave-reheated breads, containing hydrocolloids and found that the specific volume of the control cake increased by adding xanthan gum.

3.1.3. Effects of Different Gums and Gum Concentrations on Texture Profile of Cakes Baked in Different Ovens

The effects of different gum types and gum concentrations on hardness of cakes baked in MW-IR combination oven are shown in Figure 3.3. The lower hardness values were obtained for the cakes containing the gum blend and xanthan gum at all concentrations (Table A.3). The hardness values of the control cake and the cakes having guar gum at all concentrations of 0.3 and 0.6% were comparable. Heflich (1996) stated that gums can make the baked crumb rubbery and elastic. The crumb may be perceived as softer or fresher at sufficiently low levels of gums, and also as tough at elevated levels of gums. This statement can be helpful to explain why the cakes containing 1.0% guar gum were harder than 0.3% guar gum containing cake.

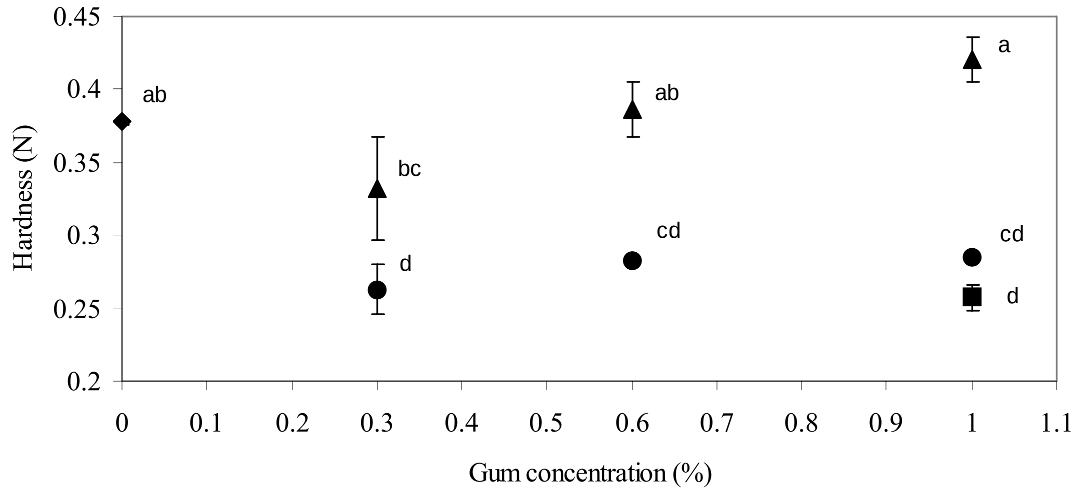


Figure 3.3 The effects of gum types and concentrations on hardness of cakes baked in MW-IR combination oven ((◆): Control cake, (●): Xanthan gum, (▲): Guar gum, (■): Gum blend)

Figure 3.4 shows the effect of gum types and gum concentrations on hardness of cakes baked in conventional oven. Similar to MW-IR combination baking, inclusion of xanthan gum (at all concentrations) and the gum blend in the formulation resulted in lower hardness values. The statistically significant highest hardness value was obtained for the 1.0% guar gum containing cake ($p<0.05$). This hardness value was also significantly higher than the hardness value of the control cake. For guar gum containing cakes, as the gum concentration increased, the hardness values increased significantly, which means that, increasing the concentration of guar gum had a negative effect on hardness of cakes (Table A.4). On the other hand, for xanthan gum containing cakes, the concentration increase had no statistically significant effect on the hardness values. Gomez et al. (2007) also found that, guar gum containing cakes at a concentration of 1.0% had higher firmness values than the control cake containing no gum.

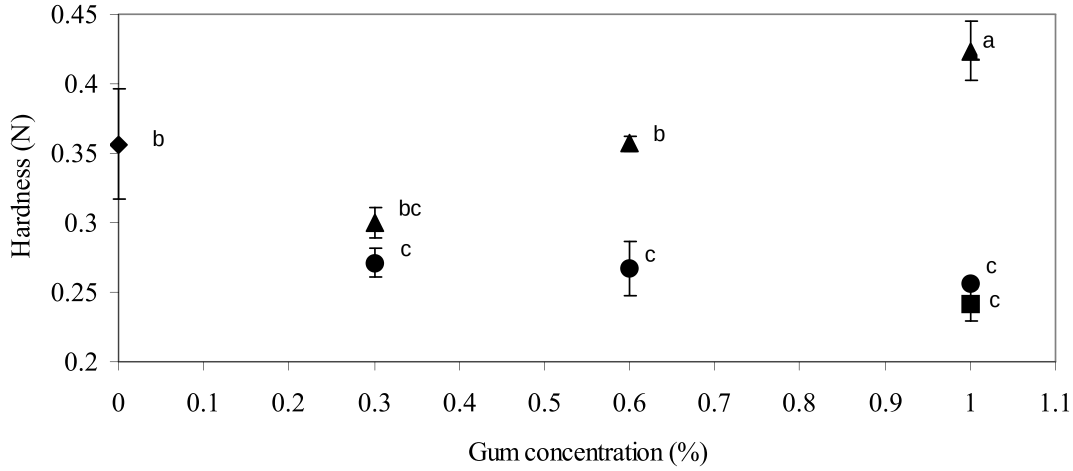


Figure 3.4 The effects of gum types and concentrations on hardness of cakes baked in conventional oven ((◆): Control cake, (●): Xanthan gum, (▲): Guar gum, (■): Gum blend)

Table 3.1 shows the effects of different gums and gum concentrations on springiness, chewiness and gumminess of the cake samples baked in MW-IR combination oven. No statistically significant difference was found between the cakes formulated with different gum types and concentrations in terms of springiness values (Table A.5). If the chewiness results are considered, there was no significant difference between the xanthan gum containing cakes at all concentrations, guar gum at 0.3% and the gum blend. However, for the guar gum containing cakes at 0.6 and 1.0% concentration, the chewiness values were significantly higher than the xanthan gum containing cakes and the gum blend. As the guar gum concentration increased from 0.3 to 1.0%, the chewiness values increased significantly ($p<0.05$). In general, the chewiness results were found to be parallel with the hardness results (Table A.6). Among the gumminess results, the significantly highest value was found for the 1.0% guar gum containing cake. It was found that, the increase in xanthan gum concentration had no significant effect on gumminess. However, the increase in guar gum concentration significantly increased the gumminess values (Table A.7). In general, these results were found to be parallel with the results of the hardness analysis.

Table 3.1 The effects of different gums and gum concentrations on springiness, chewiness, and gumminess of cake samples baked in MW-IR combination oven

Gum type and concentration	Springiness (mm)	Chewiness (N*mm)	Gumminess (N)
Control (no gum)	4.20 [a]	0.94 [a]	0.23 [b]
0.3% Guar gum	4.06 [a]	0.67 [bc]	0.18 [c]
0.3% Xanthan gum	4.06 [a]	0.60 [c]	0.17 [c]
0.6% Guar gum	4.16 [a]	0.85 [ab]	0.22 [b]
0.6% Xanthan gum	4.13 [a]	0.59 [c]	0.17 [c]
1.0% Guar gum	4.17 [a]	0.95 [a]	0.29 [a]
1.0% Xanthan gum	4.19 [a]	0.53 [c]	0.16 [c]
1.0% Gum Blend	4.12 [a]	0.55 [c]	0.16 [c]

Table 3.2 shows the effects of different gums and gum concentrations on springiness, chewiness and gumminess of the cake samples baked in conventional oven. No statistically significant difference was found between the cakes formulated with different gum types and concentrations in terms of springiness values (Table A.8). Among the chewiness results, no statistically significant difference was found between the guar gum containing cakes at 0.3% concentration, xanthan gum at all concentrations and the gum blend (Table A.9). As the guar gum concentration increased from 0.3 to 1.0%, the chewiness values increased significantly ($p<0.05$). In general, these results are similar to the chewiness results of the cakes baked in MW-IR combination oven and the results of the hardness tests. When gumminess results are considered, the xanthan gum

containing cakes at all concentrations and the gum blend had the statistically lower values (Table A.10). For the guar gum containing cakes, as the gum concentration increased, the gumminess values increased.

Table 3.2 The effects of different gums and gum concentrations on springiness, chewiness, and gumminess of cake samples baked in conventional oven

Gum type and concentration	Springiness (mm)	Chewiness (N*mm)	Gumminess (N)
Control (no gum)	4.26 [a]	0.76 [a]	0.21 [b]
0.3% Guar gum	4.07 [a]	0.59 [bc]	0.17 [c]
0.3% Xanthan gum	3.80 [a]	0.54 [c]	0.14 [d]
0.6% Guar gum	4.22 [a]	0.73 [ab]	0.21 [b]
0.6% Xanthan gum	3.84 [a]	0.56 [bc]	0.13 [d]
1.0% Guar gum	4.21 [a]	0.89 [a]	0.26 [a]
1.0% Xanthan gum	4.36 [a]	0.59 [bc]	0.14 [d]
1.0% Gum Blend	4.00 [a]	0.51 [c]	0.13 [d]

When both types of baking methods are considered, gumminess and chewiness values were found to be dependent on gum type and gum concentration. However, springiness values were independent of gum type and gum concentration. It was expected to find the chewiness and gumminess results parallel to the hardness results since, by definition, they are functions of hardness values. Gomez et al. (2007) stated that, both gumminess and chewiness are parameters dependent on hardness; therefore, their values followed a similar trend as hardness did. Ozkoc (2008) also found that chewiness values of breads baked in different ovens were dependent on gum type and gum concentration. However, springiness values were independent of gum type and gum concentration.

3.1.4. Effects of Different Gums and Gum Concentrations on Crust Color of Cakes Baked in Different Ovens

The effect of gum types and concentrations on the ΔE values of the crusts of the cakes baked in MW-IR combination and conventional oven are shown in Figure 3.5. It was found that, there was no significant difference between the ΔE values of crusts of the cakes baked in MW-IR combination oven, which means gum type or gum concentration did not have a significant effect on color of the cake crusts (Table A.11). It was also found that, there was no significant difference between the ΔE values of crusts of the cakes baked in conventional oven, indicating that neither gum type nor gum concentration had a significant effect on color of the cake crusts.

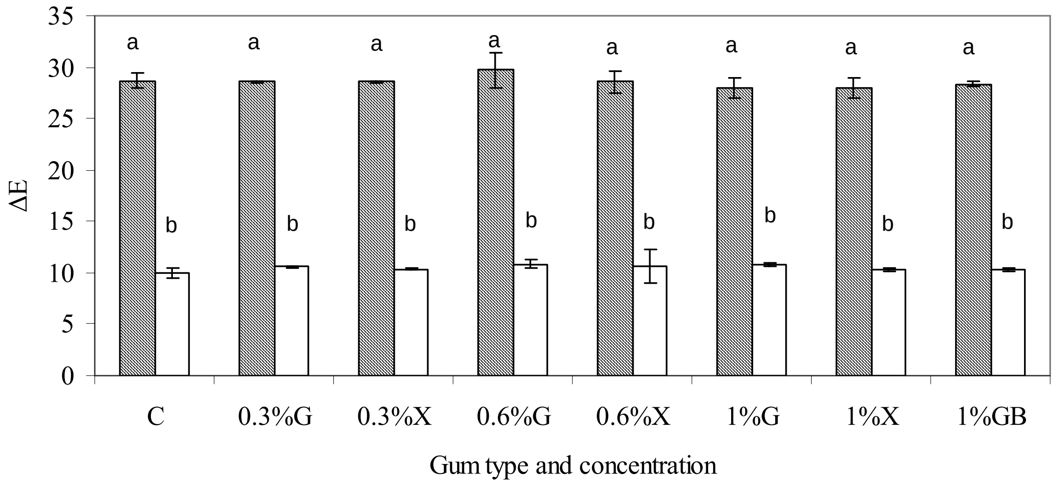


Figure 3.5 The effects of gum types and concentrations on the ΔE values of the cake crusts baked in MW-IR combination oven and conventional oven. ((▧): MW-IR combination oven, (☐): Conventional oven)

It was found that, ΔE values of the cakes baked in MW-IR combination oven were significantly higher than the ΔE values of the cakes baked in conventional oven ($p<0.05$). This may be explained by the difference in the heating mechanisms of the two baking methods. MW-IR combination baking combines microwave and infrared heating. As infrared heating has poor penetration properties, it has an impact mainly on the surface of the body which results in a higher temperature on the surface of the cakes (Sepulveda and Barbosa-Canovas, 2003). The higher temperature enhances Maillard and caramelization reactions, hence results in higher ΔE values of the crusts of the cakes baked in MW-IR combination oven.

3.1.5 Effects of Gum Type on Sensory Properties of Cakes Baked in Different Ovens

The sensory evaluations were performed according to ranking tests which are developed for measuring the food acceptability. In a ranking test, higher scores indicate a food with higher acceptability (Resurreccion, 2008). In the analysis, the cakes containing the gum blend were chosen in order to evaluate the acceptability of the cakes that had the best results in terms of the quality parameters (weight loss, specific volume and hardness). Cakes containing no gum (control cakes) were used for comparison.

Table 3.3 shows the effects of gum type on the texture and taste of cakes baked in different ovens. The highest scores for both texture and taste were obtained for the cakes containing the gum blend baked in either conventional or MW-IR combination oven ($p<0.05$). The lowest score for texture and taste was obtained for the cake containing no gum (control) and baked in MW-IR combination oven. In the presence of gum blend, the texture and taste of the cakes were not significantly affected by the oven type (Table A.12, A.13).

Table 3.3 Effects of gum type on the texture and taste of cakes baked in different ovens

GUM TYPE	OVEN TYPE	Texture	Taste
Control	**MW-IR**	1.73 [c]	1.67 [c]
1.0% Gum Blend	**MW-IR**	4.45 [a]	4.27 [a]
Control	**Conventional**	2.27 [b]	2.45 [b]
1.0% Gum Blend	**Conventional**	4.45 [a]	4.45 [a]

3.2 Effects of Different Gums and Gum Concentrations on Pasting Properties of Cakes Baked in Different Ovens

In this part of the study, effects of different gums (xanthan gum and guar gum) at 0.3% and 1.0% concentrations and their blend on the pasting properties (RVA profiles) of the cakes baked in MW-IR combination oven were investigated. For comparison, the cakes having the same formulation and baked in conventional oven were used. The 0.6% concentration of xanthan gum and guar gum were excluded since they gave neither the best nor the worst results in the quality of cakes reported in Section 3.1.

Figure 3.6 shows the effects of different gums and gum concentrations on the RVA profiles of the cakes baked in MW-IR combination oven. The peak, trough, breakdown, final and setback viscosity values obtained from these RVA curves are presented in Table 3.4. Peak, trough and final viscosity of the control cakes were found to be significantly lower than those of the cakes containing gums baked in MW-IR combination oven (Table A.14, A.15, A.17). The lower peak viscosity of the control cake might mean that the control cake had higher gelatinization degree than the cakes containing gums. In the literature, peak viscosity is related with the gelatinization enthalpy and gives an idea about the gelatinization degree of the baked products. The higher peak viscosity values means that less starch is gelatinized (Ozkoc, 2008). It was expected to find higher gelatinization degree for the control cake since the control cake did not include any gum to bind water. Chaisawang and Suphantharika (2006) also showed that, addition of gums increased peak and final viscosities of native tapioca starch.

It can be seen from Figure 3.6 that, the peak, trough and final viscosities of the cake containing 0.3% xanthan gum were lower than those of the cake containing 1.0% xanthan gum. As the gum concentration increased, the peak, trough and final viscosities increased which means the gelatinization degree decreased. This might be explained by the water binding capacity of the gums. Gums retard gelatinization by limiting the availability of water, lowering water activity and by delaying the transport of water into the starch granule needed for gelatinization (Stauffer, 1990). For the cakes baked in MW-IR combination oven, the higher values of all the parameters obtained from RVA were found for the cakes containing 1.0% xanthan gum and the gum blend. Viturawong et al. (2008) studied the gelatinization and rheological properties of rice starch/xanthan mixtures and their RVA data showed that xanthan gum addition increased the peak, breakdown, final, and setback viscosities of rice starch. In addition, the RVA profiles of the cakes (regardless of the gum type) were found to be similar to each other (Figure 3.6).

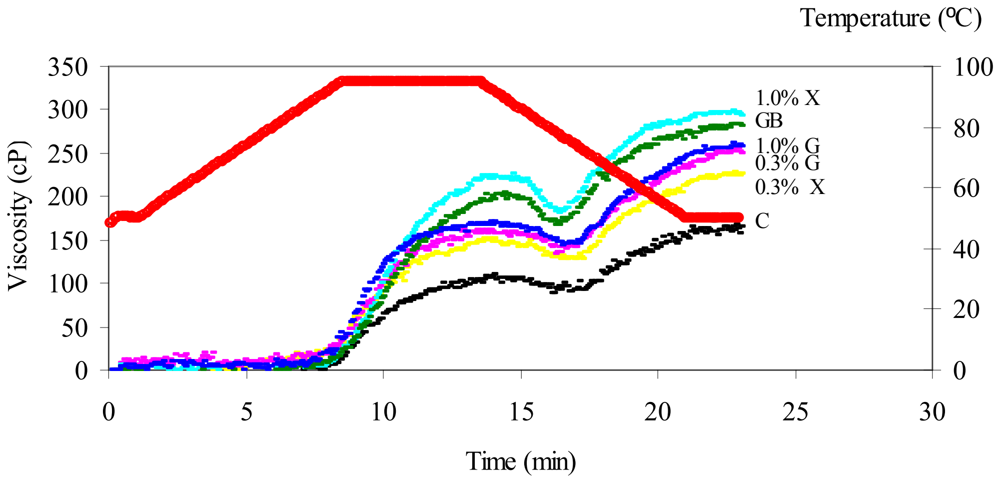


Figure 3.6 The effects of different gums and gum concentrations on the RVA profiles of cakes baked in MW-IR combination oven. ((▬): Control, (▬): 0.3% Xanthan gum, (▬): 0.3% Guar gum (▬): 1.0% Xanthan gum, (▬): 1.0% Guar gum, (▬): Gum blend)

Table 3.4 The effects of different gums and concentrations on the RVA parameters of cakes baked in MW-IR combination oven

Gum type and Concentration	Peak Viscosity (cP)	Trough Viscosity (cP)	Breakdown Viscosity (cP)	Final Viscosity (cP)	Setback Viscosity (cP)
Control	104 d	87.5 d	16.5 b	163.5 d	76 b
0.3% guar	145.5 c	125 c	20.5 ab	228 b	103 a
0.3% xanthan	161 c	132.5 bc	28.5 ab	251 bc	118.5 a
1.0% guar	169.5 bc	144.5 bc	25 ab	260.5 abc	116 a
1.0% xanthan	215 a	180 a	35 a	297.5 a	117.5 a
1.0% gum blend	190 ab	164.5 ab	25.5 ab	275.5 ab	111 a

The effects of different gums and gum concentrations on the RVA profiles of the cakes baked in conventional oven were shown in Figure 3.7. The peak, trough, breakdown, final and setback viscosity values obtained from these RVA curves are presented in Table 3.5. The RVA viscosities of the control cake in terms of peak, trough and final viscosities were found to be lower than those of the cakes containing gums baked in conventional oven (Table A.19, A.20, A.22). This means that the control cake had higher gelatinization degree than the cakes containing gums. In other words, as the gum concentration increased; the peak, trough and final viscosities increased indicating that, the gelatinization degree decreased as the gum concentration increased. This might be explained by the water binding capacity of the gums. According to the study of Achayuthakan and Suphantharika (2008), the peak viscosity of waxy corn starch increased with increasing guar gum or xanthan gum concentration. For the cakes baked in conventional oven, the highest peak viscosity values were obtained for the cake containing the gum blend. In general, the results of the cakes baked in conventional oven showed a similar trend with the ones baked in MW-IR combination oven.

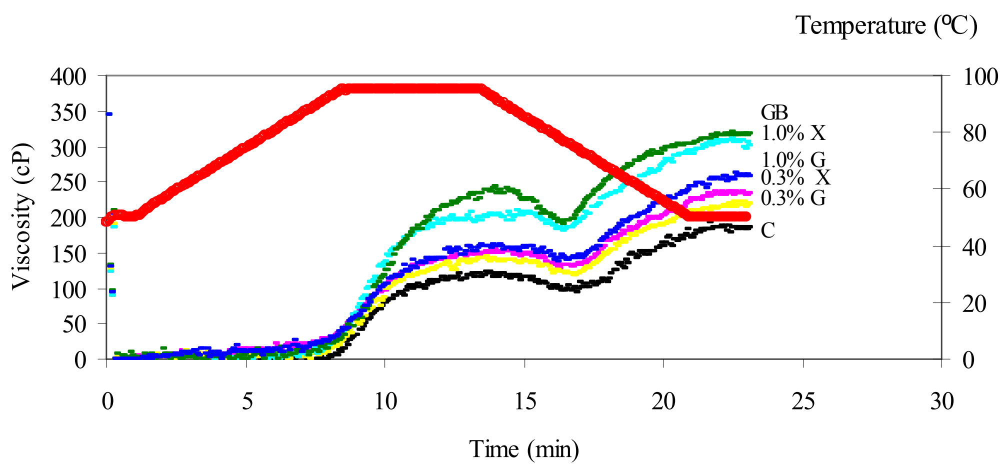


Figure 3.7 The effects of different gums and gumconcentrations on the RVA profiles of cakes baked in conventional oven ((▬): Control, (▬): 0.3% Xanthan

gum, (▬): 0.3% Guar gum (▬): 1.0% Xanthan gum, (▬): 1.0% Guar gum, (▬): Gum blend)

Table 3.5 The effects of different gums and concentrations on the RVA parameters of cakes baked in conventional oven

Gum type and concentration	Peak Viscosity (cP)	Trough Viscosity (cP)	Breakdown Viscosity (cP)	Final Viscosity (cP)	Setback Viscosity (cP)
Control	119.5 [d]	93.5 [d]	26 [b]	186 [d]	92.5 [d]
0.3% guar	151 [c]	125 [bc]	26 [b]	234.5 [c]	109.5 [bc]
0.3% xanthan	144 [c]	117 [c]	27 [b]	219.5 [c]	102.5 [cd]
1.0% guar	160 [c]	134.5 [b]	25.5 [b]	259 [b]	124.5 [ab]
1.0% xanthan	210 [b]	181 [a]	29 [b]	302 [a]	121 [ab]
1.0% gum blend	233.5 [a]	191 [a]	42.5 [a]	318 [a]	127 [a]

When the peak viscosities of the cakes baked in MW-IR combination oven and conventional oven were compared, peak viscosities of the cakes were found to be comparable.

3.3 Effects of Different Gums and Gum Concentrations on Gelatinization Degrees of Cakes Baked in Different Ovens

The effects of different gums and gum concentrations on the gelatinization degrees of the cakes baked in MW-IR combination oven and conventional oven are shown in Figure 3.8 and Figure 3.9, respectively.

As it can be seen from Figure 3.8, there was no significant difference between the gelatinization degrees of the control cake, the cake containing 0.3% guar gum and 0.3% xanthan gum. The gelatinization degrees of these cakes were significantly higher than the cakes containing 1.0% guar gum, 1.0% xanthan gum and the gum blend. It was also shown by the RVA analysis that, the peak viscosities of the cakes containing 1.0% guar gum, 1.0% xanthan gum and the gum blend were found to be higher than the control cake, the cake containing 0.3% guar gum and 0.3% xanthan gum. These results were expected, since gums retard gelatinization thus, the cake formulations containing no gum or gums at lower concentration had higher gelatinization degrees (Table A.24).

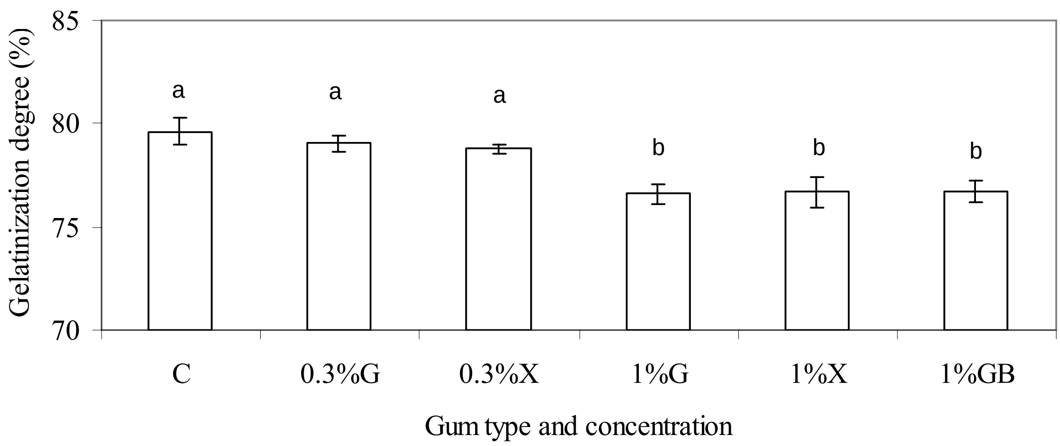


Figure 3.8 The effects of different gums and concentrations on the gelatinization degrees of cakes baked in MW-IR combination oven

If the cakes baked in conventional oven are considered, addition of xanthan gum at 1.0% or gum blend to the formulation, decreased gelatinization degrees significantly ($p<0.05$) (Table A.25) as compared to the control cake (Figure 3.9). It was also shown by the RVA analysis that, the peak viscosities of the cakes containing 1.0% xanthan gum and the gum blend were found to be higher than the control cake, the cake containing 0.3% guar gum, 1.0% guar gum and 0.3% xanthan gum. This can be explained by retardation of starch gelatinization during baking by gums limiting the availability of water and delaying the transport of water into the starch granule (Stauffer, 1990). Chaisawang and Suphantharika

(2005) also showed that addition of guar and xanthan to tapioca starches decreased gelatinization degree. The gelatinization degrees of cakes baked in different ovens were similar. This is also supported by peak viscosity results (Table 3.4, 3.5; Figure 3.6, 3.7). DSC curves with gelatinization endotherms are presented in Appendix B.

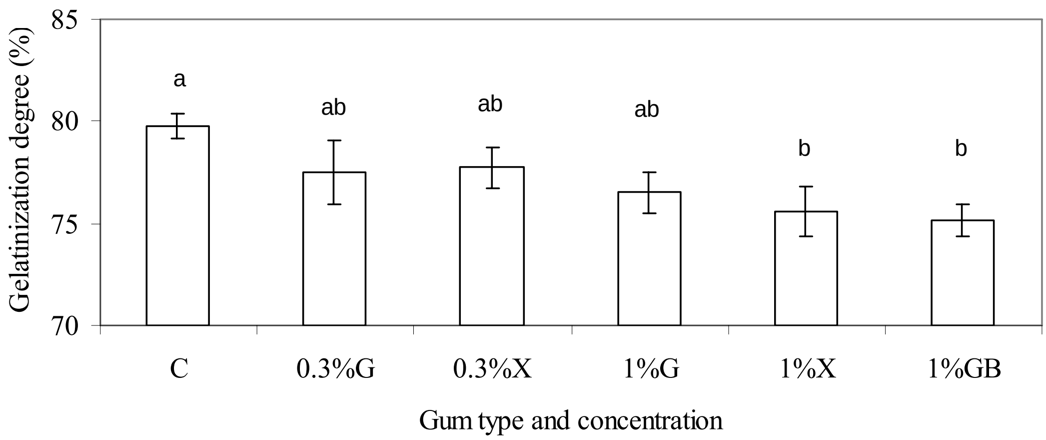


Figure 3.9 The effects of different gums and concentrations on the gelatinization degrees of cakes baked in conventional oven

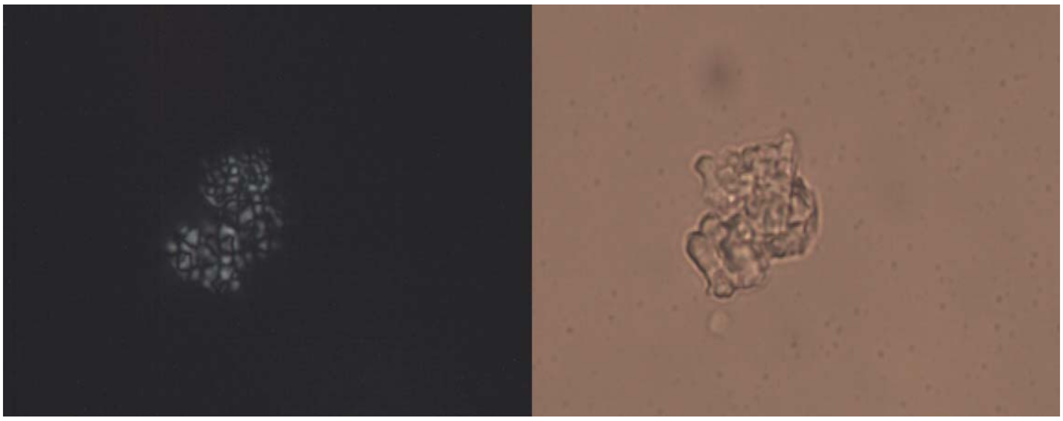
3.4 Effects of Gum Types and Gum Concentrations on Starch Birefringence Properties of Cakes Baked in Different Ovens

Microscopic examinations under polarized light (birefringence studies) are one of the most common methods used for studying the effects of heat treatment on granular structure of starch (Hoseney, 1986; Koksel et al., 1993; Guler et al., 2001).

The polarized-light (a) and the bright-field (b) microscopic examinations of rice flour, ground samples of control cake, 1.0% xanthan gum and gum blend containing cakes baked in MW-IR combination oven and in conventional oven are presented in Figure 3.10-3.16.

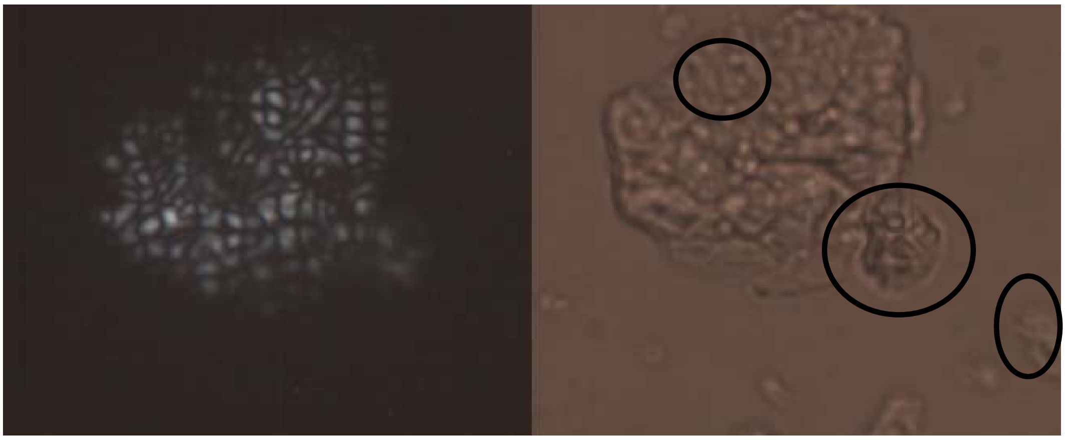
For each sample, a number of areas of the specimen were examined by bright-field and polarized-light microscopy and photographs were taken from some of these areas to demonstrate typical birefringence properties. Bright-field and polarized light microscopy examinations of the rice flour (Figure 3.10) indicated that, all starch granules of the rice flour sample displayed a clear ‘‘Maltese cross’’ image. Bright-field and polarized-light microscopy studies showed that, in all cake samples (Figures 3.11-3.16), approximately ¼ of the granules retained and ¾ of the granules lost their birefringence. The starch granules that lost their birefringence partially or completely are circled in the bright field microscopic examinations of the cake samples. Since cake batter has a high level of water, sufficient for gelatinization of starch during baking, substantial loss of birefringence in starch granules of cake samples was expected. There were also some granules that partially lost their birefringence. The partially birefringent granules had irregular shapes but retained birefringence in a portion of each granule. The difference between the birefringence properties of the rice flour and the cakes was due to the gelatinization of the starch in cake samples.

When the photographs of the cake samples baked in MW-IR combination oven (Figures 3.11, 3.13 and 3.15) and conventional oven (Figures 3.12, 3.14 and 3.16) under polarized light microscope are compared, it can be seen from the photographs that, the “Maltese cross” view of the cakes baked in two different ovens were quite similar to each other. No difference was found between the gelatinization degrees of the cakes baked in MW-IR combination oven and conventional oven by visual examination. This result is parallel with the results of the RVA (Section 3.2.) and DSC (Section 3.3.). Furthermore, no difference was observed between the birefringence properties of cake formulations containing 1.0% xanthan gum and the gum blend.



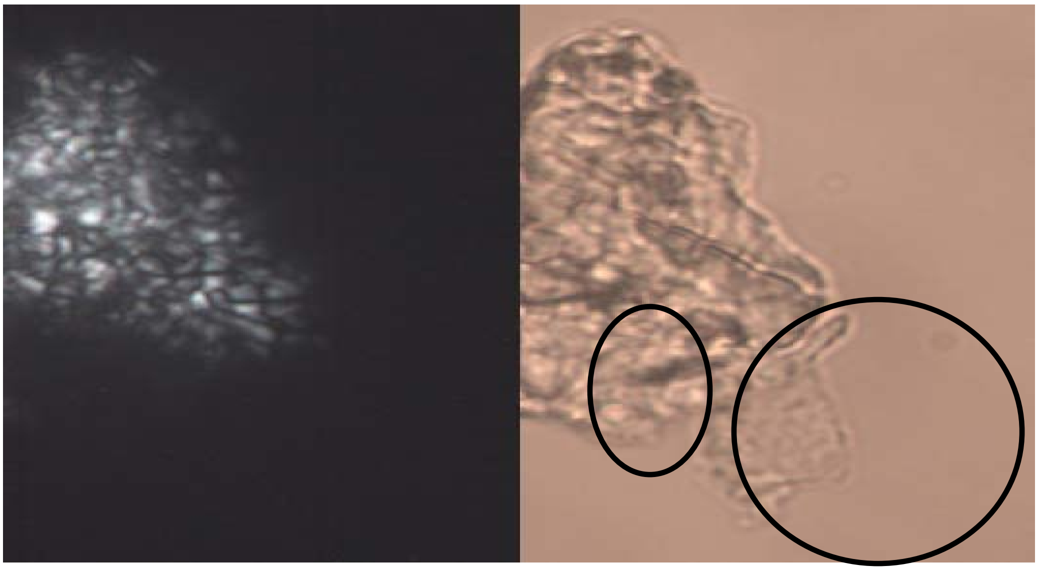
(a) (b)

Figure 3.10 The polarized-light (a) and bright-field (b) microscopic examination of rice flour



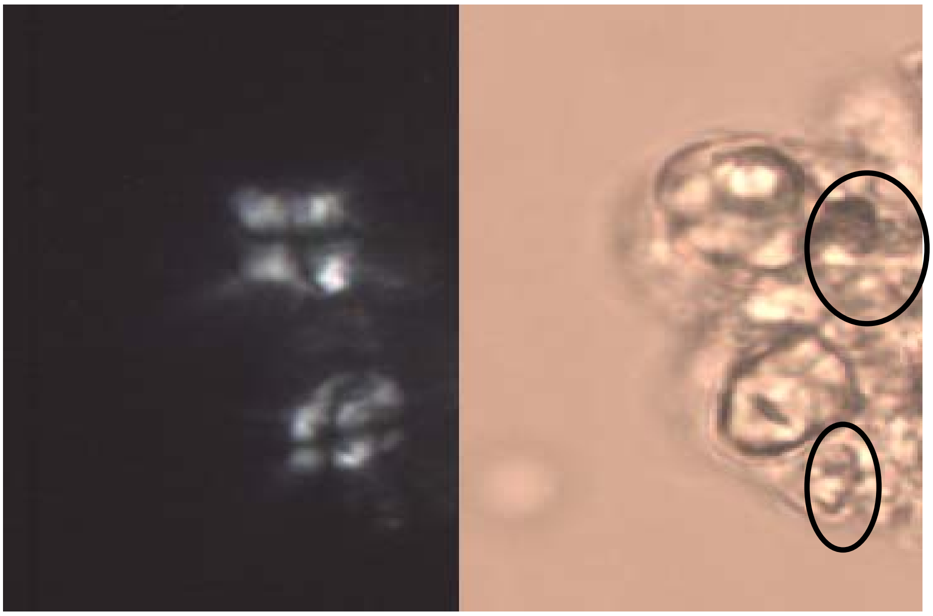
(a) (b)

Figure 3.11 The polarized-light (a) and bright-field (b) microscopic examination of control cake baked in MW-IR combination oven (The black circles on the bright field examination show the starch granules that lost their birefringence partially or completely)



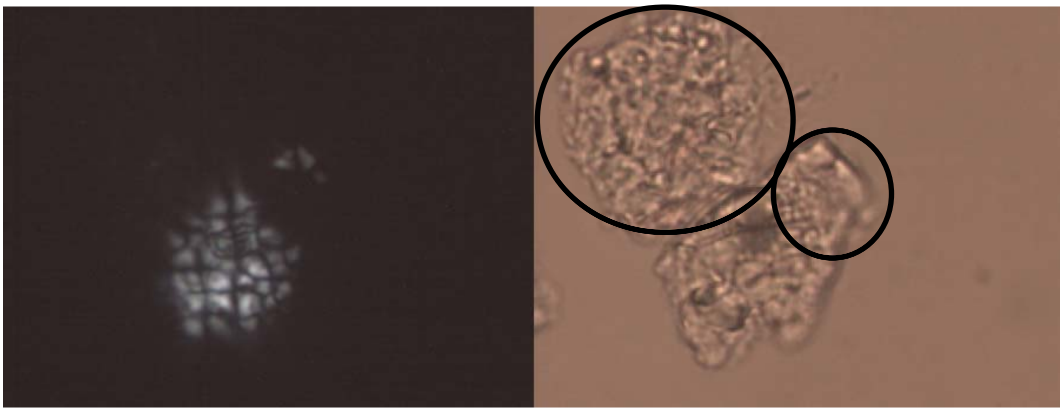
(a) (b)

Figure 3.12 The polarized-light (a) and bright-field (b) microscopic examination of control cake baked in conventional oven



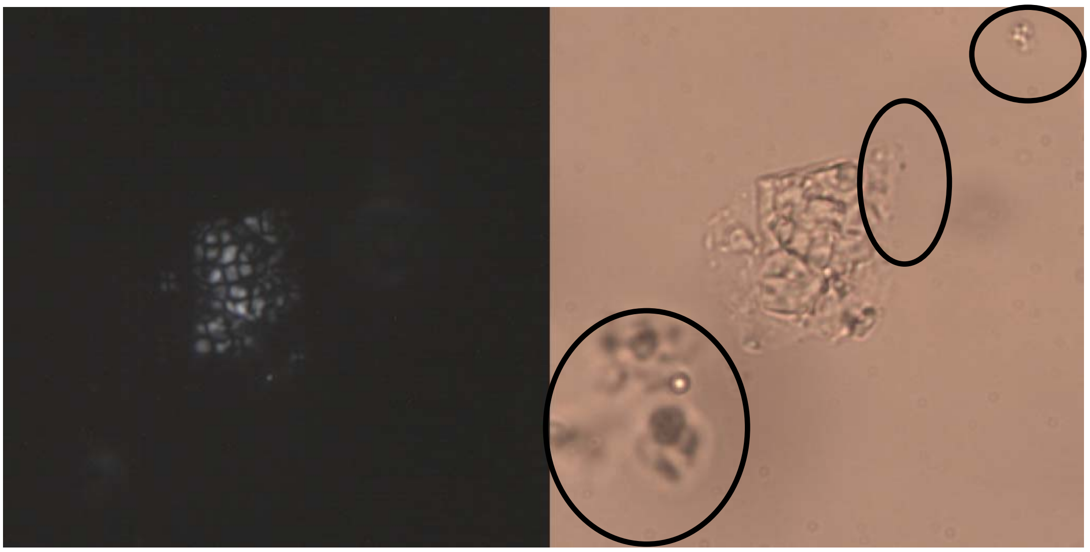
(a) (b)

Figure 3.13 The polarized-light (a) and bright-field (b) microscopic examination of 1.0% xanthan gum containing cake baked in MW-IR combination oven



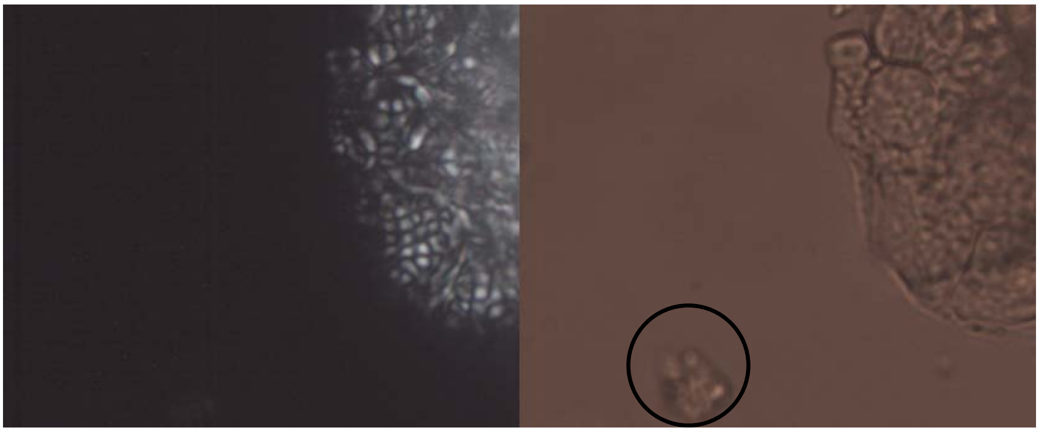
(a) (b)

Figure 3.14 The polarized-light (a) and bright-field (b) microscopic examination of 1.0% xanthan gum containing cake baked in conventional oven



(a) (b)

Figure 3.15 The polarized-light (a) and bright-field (b) microscopic examination of gum blend containing cake baked in MW-IR combination oven



(a) (b)

Figure 3.16 The polarized-light (a) and bright-field (b) microscopic examination of gum blend containing cake baked in conventional oven

3.5. Effect of Gum Types and Gum Concentrations on Staling of Cakes Baked in Different Ovens

After baking, cakes were allowed to cool down for 1 hour and stored in plastic bags at 22±2 °C for different periods of times until analyses. Hardness, weight loss, retrogradation enthalpy and RVA properties of cakes were determined during storage.

3.5.1. Effects Gums Types, Gum Concentrations and Storage Times on Weight Loss of Cakes Baked in Different Ovens

The effects of different gum types, gum concentrations and storage times on weight loss of the cake samples baked in two different ovens are presented in Figure 3.17. It can be seen from the figure that for each type of cake formulation, whether baked in conventional oven or MW-IR combination oven, the weight loss (%) increased, as the storage time increased.

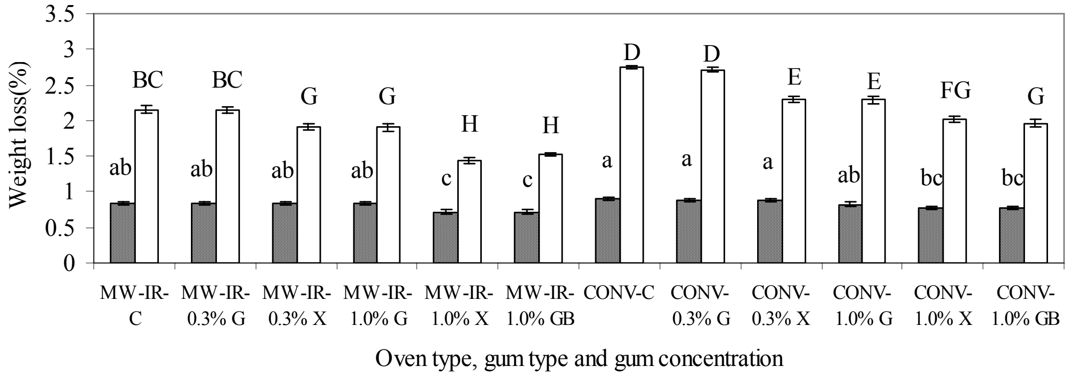


Figure 3.17 The effects of different gums, gum concentrations and storage times on weight loss of cake samples baked in two different ovens ((▧): 24 h storage period, (□): 120 h storage period) (The statistical analysis for cakes stored for 24 hours and 120 hours were performed separately. The small and capital letters were used to illustrate the cakes stored for 24 and 120 hours, respectively)

For each cake formulation, when the cakes baked in two different types of ovens and stored for 24 h are compared, the weight loss of the cakes baked in MW-IR combination oven and the cakes baked in conventional oven were found to be comparable (Figure 3.17). Weight loss of the control cake, the guar gum containing cakes and the cake containing 0.3% xanthan gum were found to be comparable. Gum blend addition and xanthan gum addition at a higher concentration (1.0%) resulted in a significant decrease in the weight loss (%) values ($p<0.05$) as compared to control cakes (Table A.26)

For each cake formulation, when the cakes baked in two different types of ovens and stored for 120 h are compared, the weight losses of cakes baked in MW-IR combination oven were found to be lower than those of the cakes baked in conventional oven (Figure 3.17). During the quality parameters analyses of the present study, the cakes baked in MW-IR combination oven were found to lose higher moisture than the cakes baked in conventional oven during baking (Figure

3.1) because of the differences in the heating mechanisms of two baking methods. Since more moisture was lost during the baking than during storage, the reason why the cakes baked in MW-IR combination oven had lower weight loss during storage might be their lower moisture content at the beginning of the storage period. The moisture content of the cakes baked in MW-IR combination oven before the storage period was approximately 5% lower than those of the cakes baked in conventional oven. Control cake and the cake containing 0.3% guar gum stored for 120 hours lost significant amount of weight for both types of ovens. The lowest weight loss (%) values were obtained when the gum blend or xanthan gum at a higher concentration (1.0%) was added to the cake formulation.

In general, higher gum concentrations resulted in lower weight loss (%) values, for both 24 and 120 h of storage. This might be explained with the high water binding property of the gums. For both storage times and oven types, lower weight loss (%) values were found for the cake containing xanthan gum at 1.0% concentration and the gum blend. After 120 h of storage, for both types of ovens, xanthan gum containing cakes had lower weight loss (%) values than the guar gum containing cakes. Similar results were found in the literature. Schiraldi et al. (1996) found that gums effectively reduced the loss of moisture content of breads during storage. In addition to that, Lent and Grant (2001) found that bagels containing xanthan gum had slightly higher crumb moisture contents. They also related moisture contents with the staling degrees.

3.5.2 Effects of Gum Types, Gum Concentrations and Storage Times on Crumb Hardness of Cakes Baked in Different Ovens

The effects of gum types, gum concentrations and storage times on hardness of the cakes baked in MW-IR combination oven and conventional oven are presented in Figure 3.18 and Figure 3.19, respectively. For both types of ovens, the hardness values increased as storage time increased, for each cake formulation. If the cake samples baked in MW-IR combination oven and stored for 120 h are considered the cake formulation containing 1.0% guar gum and the control cake had higher hardness values (Figure 3.18). The lowest hardness values were obtained for the cake formulations containing 1.0% xanthan gum and the gum blend (Table A.27). After the 120 h storage period, it was found that, 1.0% xanthan gum and gum blend addition slowed down staling approximately for 1 and 2 days, respectively, when compared with the control cake.

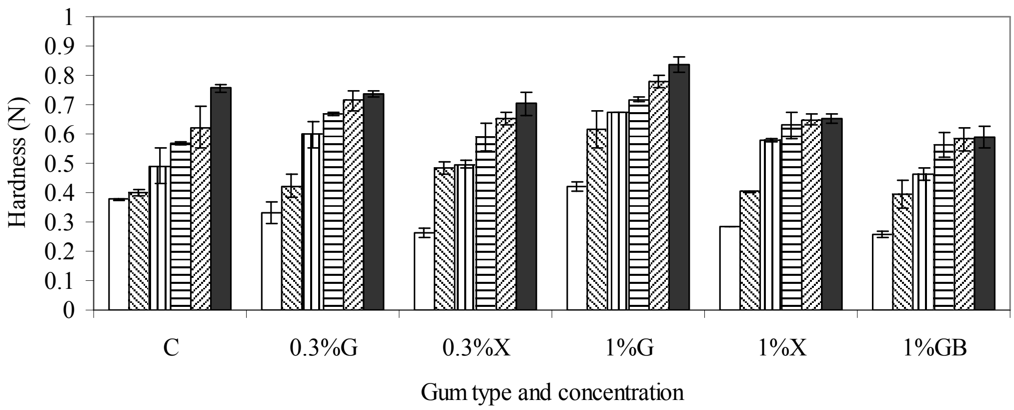


Figure 3.18 The effects of different gums, gum concentrations and storage times on hardness of cake samples baked in MW-IR combination oven ((□): 0 h, (▧):24 h, (▥):48 h, (▤):72 h, (▨):96 h, (■):120 h storage periods)

If the cake samples baked in conventional oven and stored for 120 h are considered, the guar gum containing cakes and the control cake had the highest hardness values (Figure 3.19). Similar to MW-IR baking, the lowest hardness values were obtained for the cake formulations containing 1.0% xanthan gum and the gum blend (Table A.28). After the 120 h storage period, it was found that, 1.0% xanthan gum and gum blend addition slowed down staling approximately for 2 and 3 days, respectively, when compared with the control cake. Gomez et al. (2007) observed that guar gum led to the hardest cakes during storage. They also found that, the effect of hydrocolloids on increasing the hardness during storage was dependent on the type of the gum added.

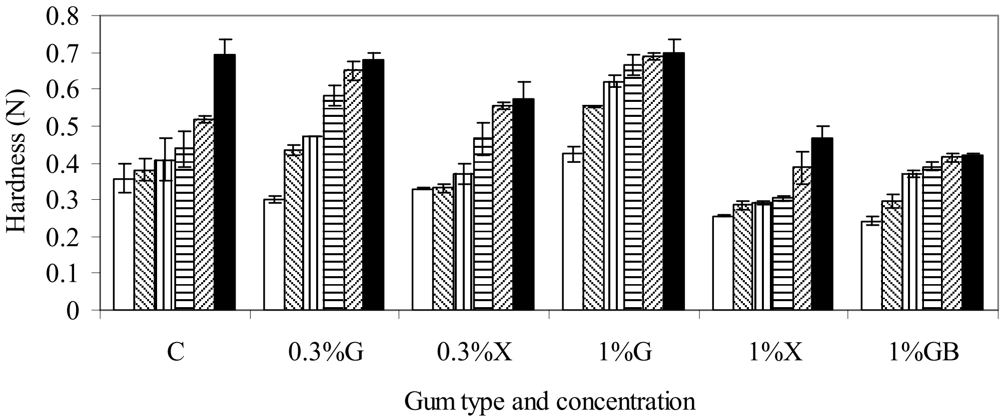


Figure 3.19 The effects of different gums, gum concentrations and storage times on hardness of cake samples baked in conventional oven ((□): 0 h, (▧):24 h, (▥):48 h, (▤):72 h, (▨):96 h, (■):120 h storage periods)

When the same cake formulations baked in two different ovens and stored for 120 h were compared, it was found that, the cakes baked in MW-IR combination oven had comparable or significantly higher hardness values than the ones baked in conventional oven depending on formulation (Figure 3.20) (Table A.29).

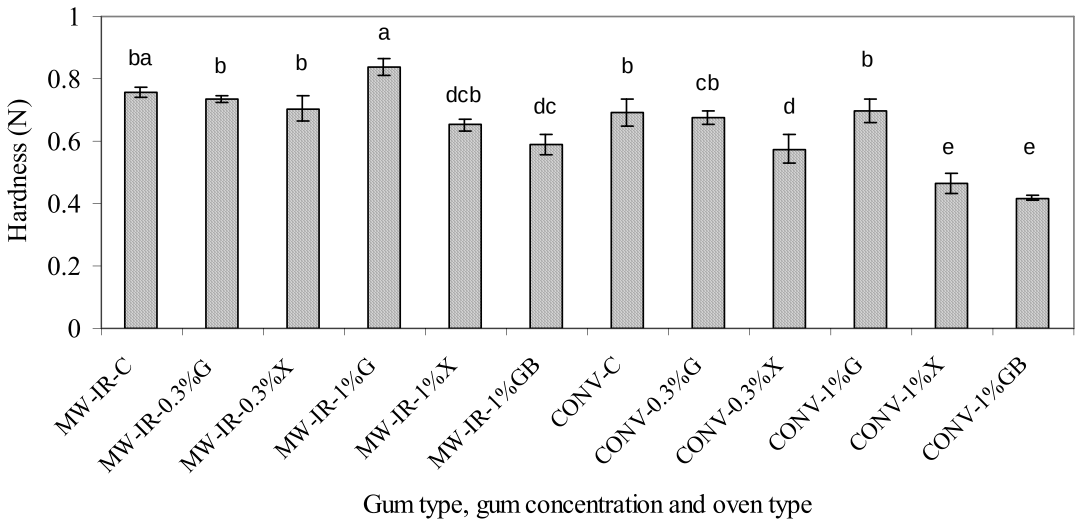


Figure 3.20 The effects of different gums, gum concentrations and oven types on hardness of cake samples stored for 120 h

If only the changes in weight loss and hardness values of the cakes during storage are considered, misleading conclusions could be drawn in terms of staling. The cakes baked in MW-IR combination oven had lower weight loss values than the cakes baked in conventional oven during 120 hour storage (Figure 3.17). Therefore, it was expected for the cakes baked in MW-IR combination oven to stale at a lower rate since; the staling rate of bread and moisture content can be correlated. However, the texture analysis results indicated that the cakes baked in MW-IR combination oven were harder than the cakes baked in conventional oven. The reason why cakes baked in MW-IR combination oven had higher hardness values might be explained by the difference between the heating mechanisms of two baking methods but not with staling. The MW-IR baking combines microwave and infrared heating and microwave heating results in higher moisture losses as compared to conventional heating, during the baking period (Section 3.1.1). The higher moisture losses during baking (Figure 3.1) might have caused higher hardness values for the fresh cakes baked in MW-IR combination oven. The higher hardness values of the cakes baked in MW-IR combination oven, during storage, might be related to the initial higher hardness values after baking.

Therefore the increased crumb hardness values of the cakes baked in MW-IR combination oven, during storage, do not seem to be related to staling but seem to be related to the higher amount of moisture loss during baking.

Ozkoc et al. (2009) investigated the physicochemical properties of breads baked in conventional, microwave and microwave-infrared combination ovens during storage and found that, hardness of bread samples increased significantly with time during storage. They related increase in firmness with the decrease in moisture content. When moisture content decreases, it accelerates the starch-starch interactions, resulting in a firmer texture. Furthermore, they found out that, the addition of xanthan-guar gum blend resulted in a significant decrease in the hardness values of samples baked in conventional and MW-IR combination oven, meaning that gum addition retarded staling in terms of hardness values. According to Rosell et al. (2001), gums are able to modify starch gelatinization and retard starch retrogradation by interacting with starch components; amylose and amylopectin.

3.5.3 Effect of Gum Types, Gum Concentrations and Storage Times on Retrogradation Enthalpies of Cakes Baked in Different Ovens

When the conditions in the calorimeter simulated those of baking; the thermograms obtained from dough samples showed two different endotherms. The first endotherm is known as the starch gelatinization endotherm and the second one is the retrogradation endotherm (León et al., 1997). It was also stated that, for the retrogradation endotherm, endothermic peak temperatures may vary from about 50 °C to 60 °C, depending on the storage temperature, starch concentration, and aging times (Zobel and Kulp, 1996). DSC curves with retrogradation endotherms are given in Appendix B.

In retrograded starch, the retrogradation enthalpy provides a quantitative measure of the energy transformation that occurs during the melting of recrystallized amylopectin as well as precise measurements of the transition temperatures of this endothermic event (Karim et al., 2000). In the literature amylopectin retrogradation was evaluated according to the endotherm situated at a temperature lower than that of gelatinization. This endotherm is called the "staling endotherm" and its magnitude is known to increase during storage (León et al., 1997).

The retrogradation enthalpies of cakes baked in MW-IR combination oven and stored for 24 h and 120 h are presented in Figure 3.21. It can be seen from the figure that, for each cake formulation, the retrogradation enthalpy increased as the storage time increased from 24 h to 120 h. After 24 h of storage, the significantly lowest retrogradation enthalpy was found for the cake containing the gum blend. The significantly highest retrogradation enthalpy, for both 24 and 120 hours, was obtained for the cake having 1.0% guar gum (Table A.30).

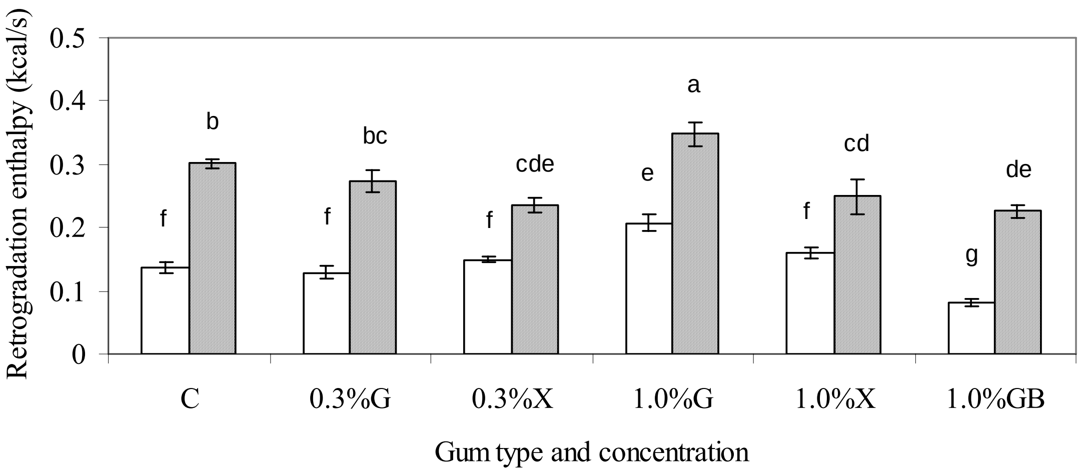


Figure 3.21 The effects of different gums, gum concentrations and storage times on retrogradation enthalpies of cake samples baked in MW-IR combination oven ((□): 24 hour, (▧): 120 hour)

The retrogradation enthalpies of cakes baked in conventional oven and stored for 24 h and 120 h are presented in Figure 3.22. It can be seen from the figure that, for each cake formulation, the retrogradation enthalpy increased as the storage time increased from 24 h to 120 h. These results are in accordance with those of cakes baked in MW-IR combination oven.

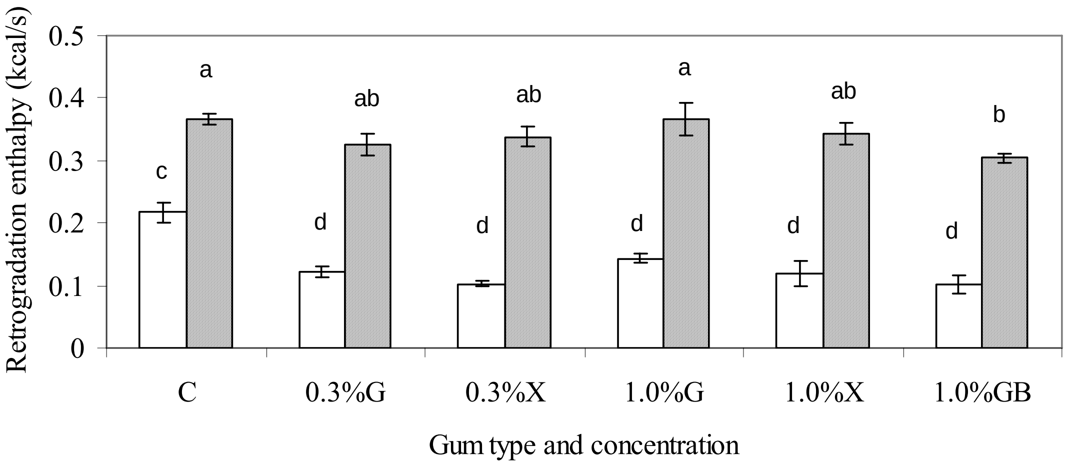


Figure 3.22 The effects of different gums, gum concentrations and storage times on retrogradation enthalpies of cake samples baked in conventional oven ((□): 24 hour, (▨): 120 hour)

Among the cakes baked in conventional oven and stored for 24 h, addition of gums to the formulation resulted in a significant decrease in the retrogradation enthalpy values when compared to the control cake. After 120 h storage, it can be seen from the figure that, only the addition of the gum blend resulted in a significant decrease in the retrogradation enthalpy values when compared to the control cake (Table A.31). This might be explained by the synergistic effect of using xanthan and guar gum together.

If the gelatinization degree of a cake sample is higher, retrogradation enthalpy would also be higher during the storage period. This means that, it would be expected to find a cake sample with a higher staling rate if its gelatinization degree is higher. This is due to fact that, during gelatinization starch granules rapture and firstly amylose and then amylopectin is leached out of the starch granules. As the amount of leached material increases, the interaction sites for amylose, amylopectin and water increases. During the cooling stage of the starch gels, the bonds with water are broken and new bonds are made within the amylose and amylopectin molecules. Therefore, if the initial number of bonding sites is high, the staling rate will also be high. Gums retard gelatinization by limiting the availability of water, lowering water activity and by delaying the transport of water into the starch granule needed for gelatinization (Stauffer, 1990). Hence, retardation of gelatinization of the cakes by gums would also retard the retrogradation enthalpies of the cake samples. Ozkoc et al. (2009) found that addition of gum reduced retrogradation enthalpy meaning that amylopectin retrogradation was retarded. According to Chaisawang and Suphantharika (2006) the retrogradation enthalpy values of gum added starch samples were lower than samples containing only starch. They associated their results with a reduction in water availability causing partial gelatinization of crystalline regions in the starch granules and starch-gum interactions.

When the same cake formulations baked in two different ovens and stored for 120 h were compared, the cakes baked in MW-IR combination oven had comparable retrogradation enthalpies with the cakes baked in conventional oven (Figure 3.21, 3.22) This means that, depending on formulation, the cakes baked in MW-IR combination oven staled at a similar rate with the ones baked in conventional oven.

3.5.4. Effects of Gum Types and Storage Times on RVA Profile Parameters of Cakes Baked in Different Ovens

In the literature, it was stated that the tendency of a starch to retrograde can be studied from its pasting behavior, usually by observing changes in viscosity using RVA (Karim et al., 2000; Patel et al., 2005).

When the effects of gum types, gum concentrations and storage times on the peak viscosities of cakes baked in two different ovens are considered, for each cake formulation a statistically significant difference was found in the peak viscosities as the storage time increased to 120 h (Table A.32). A similar result was also reported by Ozkoc (2008) who investigated the quality and the staling of breads with different gum formulations baked in different ovens. Ozkoc (2008) showed that, the peak viscosities increased as the storage time of the breads increased.

In the literature, setback viscosity was reported to be related with retrogradation by many researchers (Lent and Grant, 2001; Collar, 2003; Sopade et al., 2006). The effects of gum types, gum concentrations and storage times on the setback viscosities of the cakes baked in two different ovens are presented in Figure 3.23. For each type of cake formulation, baked in MW-IR combination oven or conventional oven, a statistically significant difference in the setback viscosities was found as the storage time increased to 120 h (Table A.33). Similar results was also stated by Ozkoc (2008) who reported that, the setback viscosities increased as the storage time of the breads increased.

As stated by Rojas et al. (1998), retrogradation was responsible for the firming of bread crumb. They concluded that, it was convenient to include additives and/or ingredients that promote a reduction of the setback, and in consequence, a delay of firming of the crumb. They also stated that xanthan gum could be considered as a useful anti-staling additive in the bread making process. Ozkoc et al. (2009) found that gum addition to the bread formulation resulted in an increase in viscosity values of most of the samples baked in different ovens, during storage which can not be related to starch retrogradation.

When the cake samples baked in only MW-IR combination oven or in only conventional oven are examined, the values of the setback viscosities may be confusing. Since all the RVA viscosities of control cakes were found to be lower than those of cakes containing gums; the values of the setback viscosity, which was also lower, may lead to wrong conclusions. It was stated by some researchers (Collar, 2003; Chaisawang and Suphantharika, 2006; Ozkoc, 2008) that viscosity of starch/hydrocolloid systems after heating and cooling was greater than systems containing only starch, which was related to the water binding capacity of the gums. Thus, the increase in viscosity in the presence of gum can not be related to staling, because gums increase the viscosity by binding water and decreasing its availability. Therefore, the setback viscosities were converted to percent change in setback viscosities to study staling during storage.

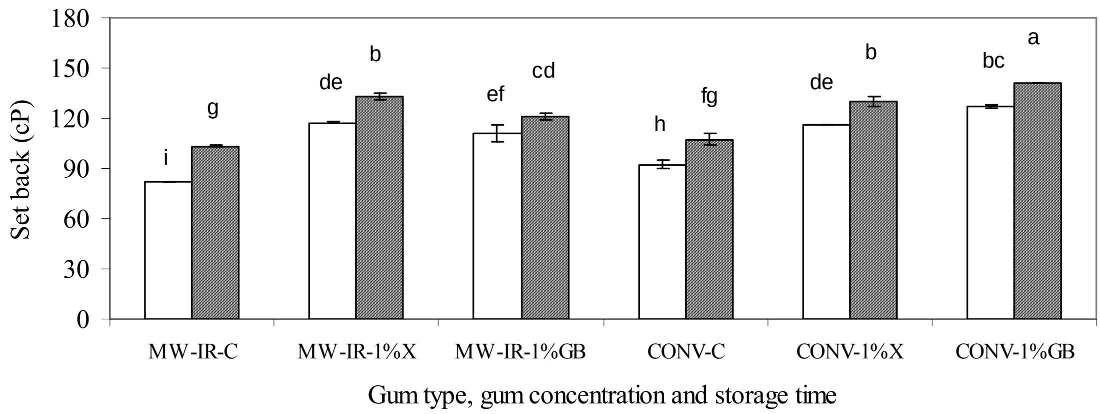


Figure 3.23 The effects of gum types, gum concentrations and storage times on the setback viscosities of cakes baked in two different ovens ((□): 0 hour, (▨): 120 hour)

The effects of gum type and concentration on the change of setback viscosity (%) of the cakes baked in MW-IR combination oven and stored for 120 h are presented in Figure 3.24. It was found that, the change in setback viscosity (%) of the control cake was higher than the 1.0% xanthan gum and gum blend containing cakes. This shows to the faster staling rate of the control cake as compared to gum containing cakes. This result is in agreement with the retrogradation enthalpy results of the cakes stored for 120 h (Figure 3.21).

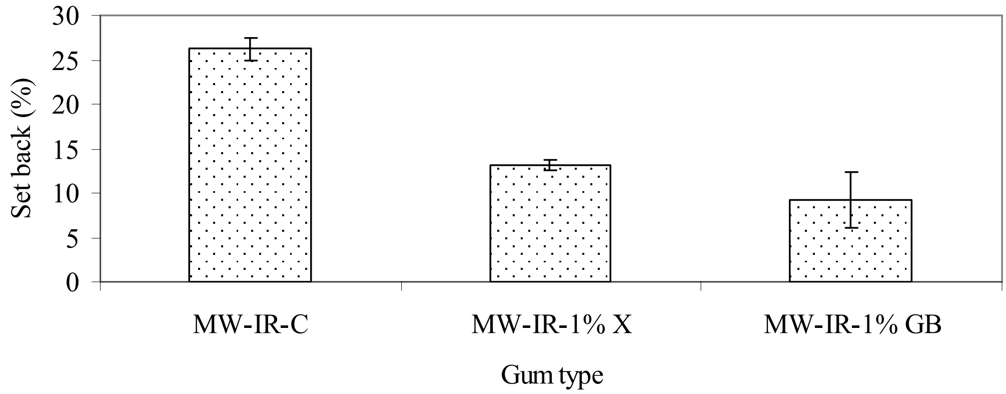


Figure 3.24 The effects of gum type and concentration on the setback (%) of the cakes baked in MW-IR combination oven (storage time 120 h)

The effects of gum type and concentration on the change in setback viscosity (%) of the cakes baked in conventional oven and stored for 120 h are presented in Figure 3.25. When 1.0% xanthan gum or gum blend was added to the formulation, the change in setback viscosity (%) values decreased. A higher result was expected for the control cake, since control cake had higher retrogradation enthalpy (Figure 3.22) and higher weight loss (Figure 3.17) during storage. In the presence of gums, change in setback viscosities (%) of cakes, baked in different ovens were similar showing that their staling rates were comparable.

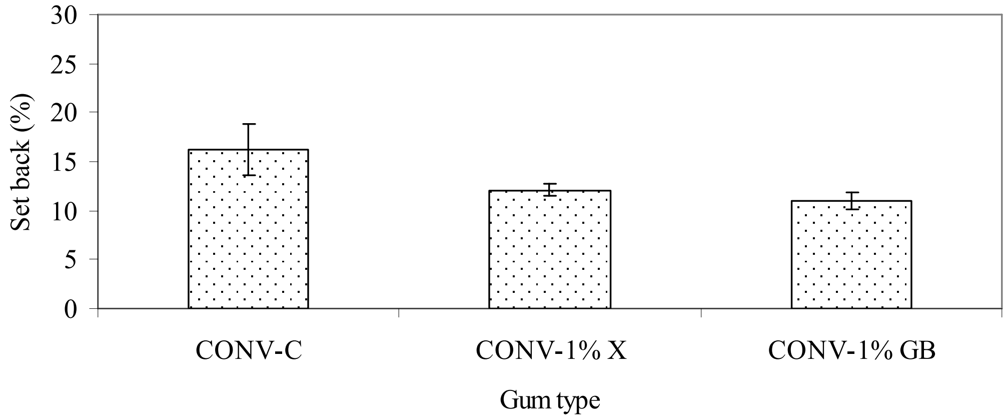


Figure 3.25 The effects of gum type and concentration on the setback (%) of the cakes baked in conventional oven (storage time 120 h)

3.6. Gluten Analysis

"Gluten-free" food products, defined in Codex guidelines as containing <200 ppm gluten if cereal derived and <20 ppm for non-cereal derived foods. According to the gluten contamination test results, neither of the ingredients nor the cake samples is contaminated with gluten. All the gluten concentrations were found to be either 0 or <5 ppm.

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

Quality parameters such as weight loss, specific volume and hardness, were found to be dependent on gum type and gum concentration for cakes baked in MW-IR combination oven and conventional oven. Among the gums studied, the addition of xanthan-guar gum blend to the formulation resulted in an increase in specific volume as well as a decrease in weight loss and hardness of the cakes when compared with the control cakes, for both types of ovens. The scores of the texture and taste evaluations of the cake samples were found to be higher for the cakes containing the gum blend either baked in MW-IR combination oven or conventional oven.

The RVA profile parameters of the control cakes in terms of peak, trough and final viscosities were found to be lower than those of the cakes containing gums, baked in both types of ovens. As the gum concentration increased; the peak, trough and final viscosities increased indicating that, the gelatinization degree decreased. When the DSC analyses are considered, the cake formulations that had no gum or gums at lower concentration were found to have higher gelatinization degrees. The highest gelatinization degree was obtained in the control cake. Gelatinization degrees of the cakes baked in different ovens were found to be similar.

Bright-field and polarized light microscopy examinations of the rice flour indicated that, all starch granules of the rice flour sample displayed a clear ‘‘Maltese cross’’. Birefringence studies showed that, in all cake samples, approximately ¼ of the granules retained and ¾ of the granules lost their birefringence. No difference was found between the gelatinization degrees of the cakes baked in MW-IR combination oven and conventional oven by visual examination.

As long as weight loss or retrogradation enthalpy values were considered, staling rate of cakes baked in MW-IR combination oven were almost comparable with that of conventionally baked ones. Gum blend addition to the cake formulation resulted in a significant decrease in the weight loss (%) values as compared to the control cake. In general, higher gum concentrations resulted in lower weight loss, retrogradation enthalpy and the change in setback viscosity of the cakes as compared to the control cake, meaning that staling was retarded.

The effect of hydrocolloids on hardness increase during storage was dependent on the type of the gum added. The lowest hardness values were obtained for the cake formulations containing 1.0% xanthan gum and the gum blend, for both types of baking methods. When the same cake formulations baked in two different ovens and stored for 120 h were compared, it was found that, the cakes baked in MW-IR combination oven had comparable or significantly higher hardness values than the ones baked in conventional oven depending on the formulation.

Xanthan-guar gum blend was found to be the most effective hydrocolloid to improve quality and to retard staling of gluten free cakes baked in MW-IR combination and conventional oven. Xanthan-guar gum blend can be recommended to be used in cake formulations to be baked in both types of ovens to retard staling. Microwave-infrared combination oven made it possible to produce gluten-free cakes with similar quality with the ones baked in conventional oven and reduced the baking time by significantly.

As future work, the effects of other ingredients (emulsifiers, gum-emulsifier blends, starches, etc.) with varying blend ratios may be studied to obtain the best gluten free formulation in terms of improving product quality and retarding staling. In addition to these, instead of rice flour, different flours such as corn and chestnut flours may be used in the cake formulation.

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APPENDIX A

ANOVA AND DUNCAN TEST TABLES

Table A.1 ANOVA and Duncan Single Range Test Table for weight loss of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

weightloss

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	4	14.35402	.72026915	.36013458	13.2079124	15.5001303	13.68524	15.20000
2	4	13.74542	.71039532	.35519766	12.6150267	14.8758217	12.81800	14.54006
3	4	12.71720	.19646296	.09823148	12.4045852	13.0298180	12.54941	12.99709
4	4	13.00812	.36507542	.18253771	12.4271998	13.5890327	12.68293	13.49754
5	4	12.60236	.60710559	.30355279	11.6363198	13.5684008	11.80000	13.20000
6	4	12.72349	.33480607	.16740303	12.1907421	13.2562444	12.33959	13.07768
7	4	12.39262	1.22918442	.61459221	10.4367141	14.3485275	10.76770	13.40000
8	4	12.37238	.14947195	.07473598	12.1345398	12.6102262	12.18075	12.53000
9	4	7.8443806	.90256288	.45128144	6.4082017	9.2805596	6.69331	8.90000
10	4	6.5988509	.29281331	.14640666	6.1329196	7.0647822	6.25621	6.97211
11	4	6.1221058	.25503298	.12751649	5.7162914	6.5279202	5.78842	6.40000
12	4	6.4975000	.29443449	.14721724	6.0289890	6.9660110	6.10000	6.80000
13	4	5.9994500	.21559407	.10779704	5.6563917	6.3425083	5.76430	6.23430
14	4	6.4540420	.12601301	.06300651	6.2535272	6.6545568	6.28743	6.59341
15	4	5.4437625	.91837094	.45918547	3.9824294	6.9050956	4.60000	6.28743
16	4	5.3627764	.30643838	.15321919	4.8751646	5.8503883	5.10000	5.79421
Total	64	9.6399056	3.48413805	.43551726	8.7695938	10.5102174	4.60000	15.20000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven, 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

ANOVA

weightloss

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	748.988	15	49.933	151.857	.000
Within Groups	15.783	48	.329		
Total	764.771	63			

weightloss

Duncan[a]

caketype	N	Subset for alpha = .05					
		1	2	3	4	5	6
16	4	5.3627764					
15	4	5.4437625					
13	4	5.9994500	5.9994500				
11	4	6.1221058	6.1221058				
14	4		6.4540420				
12	4		6.4975000				
10	4		6.5988509				
9	4			7.8443806			
8	4				12.37238		
7	4				12.39262		
5	4				12.60236		
3	4				12.71720		
6	4				12.72349		
4	4				13.00812	13.00812	
2	4					13.74542	13.74542
1	4						14.35402
Sig.		.093	.196	1.000	.177	.075	.140

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.2 ANOVA and Duncan Single Range Test Table for specific volume of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

specificvolume

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	4	1.4650000	.02645751	.01322876	1.4229002	1.5070998	1.44000	1.50000
2	4	1.4075000	.05439056	.02719528	1.3209525	1.4940475	1.33000	1.45000
3	4	1.5875000	.07500000	.03750000	1.4681583	1.7068417	1.49000	1.66000
4	4	1.3525000	.05439056	.02719528	1.2659525	1.4390475	1.31000	1.43000
5	4	1.5900000	.08679478	.04339739	1.4518901	1.7281099	1.51000	1.67000
6	4	1.3750000	.09146948	.04573474	1.2294516	1.5205484	1.31000	1.51000
7	4	1.7875000	.00500000	.00250000	1.7795439	1.7954561	1.78000	1.79000
8	4	2.1300000	.06928203	.03464102	2.0197568	2.2402432	2.07000	2.19000
9	4	1.3350000	.15588457	.07794229	1.0869529	1.5830471	1.20000	1.47000
10	4	1.4250000	.09574271	.04787136	1.2726520	1.5773480	1.30000	1.50000
11	4	1.3775000	.19805302	.09902651	1.0623534	1.6926466	1.21000	1.64000
12	4	1.3775000	.09464847	.04732424	1.2268932	1.5281068	1.30000	1.51000
13	4	1.5525000	.13841363	.06920682	1.3322530	1.7727470	1.42000	1.70000
14	4	1.4000000	.11547005	.05773503	1.2162614	1.5837386	1.30000	1.50000
15	4	1.7000000	.07071068	.03535534	1.5874835	1.8125165	1.60000	1.75000
16	4	1.7200000	.02708013	.01354006	1.6769095	1.7630905	1.68000	1.74000
Total	64	1.5364063	.22536297	.02817037	1.4801123	1.5927002	1.20000	2.19000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven, 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

Table A.2 Continued

ANOVA

specificvolume

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.741	15	.183	19.130	.000
Within Groups	.459	48	.010		
Total	3.200	63			

specificvolume

Duncan[a]

		Subset for alpha = .05						
caketype	N	1	2	3	4	5	6	7
9	4	1.3350000						
4	4	1.3525000						
6	4	1.3750000						
11	4	1.3775000						
12	4	1.3775000						
14	4	1.4000000	1.4000000					
2	4	1.4075000	1.4075000					
10	4	1.4250000	1.4250000					
1	4	1.4650000	1.4650000	1.4650000				
13	4		1.5525000	1.5525000	1.5525000			
3	4			1.5875000	1.5875000	1.5875000		
5	4			1.5900000	1.5900000	1.5900000		
15	4				1.7000000	1.7000000	1.7000000	
16	4					1.7200000	1.7200000	
7	4						1.7875000	
8	4							2.1300000
Sig.		.117	.053	.105	.055	.085	.239	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.3 ANOVA and Duncan Single Range Test Table for hardness of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

hardness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	.3777450	.00282418	.00199700	.3523707	.4031193	.37575	.37974
2	2	.3318590	.05030782	.03557300	-.1201388	.7838568	.29629	.36743
3	2	.2628805	.02428983	.01717550	.0446451	.4811159	.24571	.28006
4	2	.3861175	.02642529	.01868550	.1486957	.6235393	.36743	.40480
5	2	.2821065	.00289984	.00205050	.2560524	.3081606	.28006	.28416
6	2	.4201610	.02171949	.01535800	.2250191	.6153029	.40480	.43552
7	2	.2853785	.00172746	.00122150	.2698579	.3008991	.28416	.28660
8	2	.2572235	.01223365	.00865050	.1473085	.3671385	.24857	.26587
Total	16	.3254339	.06293988	.01573497	.2918956	.3589722	.24571	.43552

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

hardness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.055	7	.008	14.084	.001
Within Groups	.004	8	.001		
Total	.059	15			

Table A.3 Continued

hardness

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
8	2	.2572235			
3	2	.2628805			
5	2	.2821065	.2821065		
7	2	.2853785	.2853785		
2	2		.3318590	.3318590	
1	2			.3777450	.3777450
4	2			.3861175	.3861175
6	2				.4201610
Sig.		.294	.078	.059	.123

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.4 ANOVA and Duncan Single Range Test Table for hardness of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

hardness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
9	2	.3565535	.05590174	.03952850	-.1457037	.8588107	.31703	.39608
10	2	.3004230	.01530038	.01081900	.1629546	.4378914	.28960	.31124
11	2	.2713340	.01436275	.01015600	.1422898	.4003782	.26118	.28149
12	2	.3568290	.00790121	.00558700	.2858394	.4278186	.35124	.36242
13	2	.2671955	.02771081	.01959450	.0182238	.5161672	.24760	.28679
14	2	.4234710	.02977627	.02105500	.1559419	.6910001	.40242	.44453
15	2	.2555065	.00296207	.00209450	.2288934	.2821196	.25341	.25760
16	2	.2412690	.01640063	.01159700	.0939151	.3886229	.22967	.25287
Total	16	.3090727	.06441689	.01610422	.2747474	.3433980	.22967	.44453

Cake types: 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

Table A.4 Continued

ANOVA

hardness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.057	7	.008	11.651	.001
Within Groups	.006	8	.001		
Total	.062	15			

hardness

Duncan[a]

caketype	N	Subset for alpha = .05		
		1	2	3
16	2	.2412690		
15	2	.2555065		
13	2	.2671955		
11	2	.2713340		
10	2	.3004230	.3004230	
9	2		.3565535	
12	2		.3568290	
14	2			.4234710
Sig.		.071	.074	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.5 ANOVA and Duncan Single Range Test Table for springiness of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

springiness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	4.2031901	.02679009	.01894345	3.9624907	4.4438895	4.18425	4.22213
2	2	4.0556316	.12871306	.09101388	2.8991906	5.2120726	3.96462	4.14665
3	2	4.0624309	.01155860	.00817316	3.9585810	4.1662807	4.05426	4.07060
4	2	4.1611265	.02047923	.01448100	3.9771279	4.3451251	4.14665	4.17561
5	2	4.1326862	.11091463	.07842849	3.1361578	5.1292146	4.05426	4.21111
6	2	4.1700694	.00783209	.00553812	4.0997008	4.2404379	4.16453	4.17561
7	2	4.1897535	.03020926	.02136117	3.9183341	4.4611729	4.16839	4.21111
8	2	4.1145319	.01639790	.01159507	3.9672025	4.2618612	4.10294	4.12613
Total	16	4.1361775	.07045608	.01761402	4.0986341	4.1737209	3.96462	4.22213

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

springiness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.043	7	.006	1.569	.270
Within Groups	.031	8	.004		
Total	.074	15			

springiness

Duncan[a]

caketype	N	Subset for alpha = .05 1
2	2	4.0556316
3	2	4.0624309
8	2	4.1145319
5	2	4.1326862
4	2	4.1611265
6	2	4.1700694
7	2	4.1897535
1	2	4.2031901
Sig.		.063

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.6 ANOVA and Duncan Single Range Test Table for chewiness of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

chewiness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	.9351080	.04443840	.03142269	.5358448	1.3343711	.90369	.96653
2	2	.6744377	.13022458	.09208269	-.4955838	1.8444592	.58236	.76652
3	2	.5982384	.01418023	.01002694	.4708341	.7256428	.58821	.60827
4	2	.8493448	.11713138	.08282439	-.2030389	1.9017285	.76652	.93217
5	2	.5889914	.02725757	.01927401	.3440919	.8338909	.56972	.60827
6	2	.9520977	.02818317	.01992851	.6988820	1.2053134	.93217	.97203
7	2	.5258650	.06201667	.04385241	-.0313327	1.0830626	.48201	.56972
8	2	.5453528	.13590132	.09609675	-.6756721	1.7663778	.44926	.64145
Total	16	.7086795	.18127475	.04531869	.6120850	.8052740	.44926	.97203

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

chewiness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.436	7	.062	8.791	.003
Within Groups	.057	8	.007		
Total	.493	15			

Table A.6 Continued

chewiness

Duncan[a]

caketype	N	Subset for alpha = .05		
		1	2	3
7	2	.5258650		
8	2	.5453528		
5	2	.5889914		
3	2	.5982384		
2	2	.6744377	.6744377	
4	2		.8493448	.8493448
1	2			.9351080
6	2			.9520977
Sig.		.139	.071	.275

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.7 ANOVA and Duncan Single Range Test Table for gumminess of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

gumminessMWIR

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	4	.2267371	.02552351	.01276175	.1861235	.2673507	.20035	.24980
2	4	.1821068	.01848019	.00924009	.1527007	.2115129	.15657	.20013
3	4	.1656312	.01258425	.00629212	.1456068	.1856555	.14847	.17862
4	4	.2214498	.03148304	.01574152	.1713533	.2715464	.19083	.24980
5	4	.1672528	.01650488	.00825244	.1409899	.1935158	.15186	.18739
6	4	.2936520	.01114673	.00557337	.2759150	.3113889	.28507	.30989
7	4	.1633956	.00981931	.00490965	.1477709	.1790203	.15041	.17296
8	4	.1632392	.01106462	.00553231	.1456329	.1808455	.15515	.17930
Total	32	.1979331	.04717160	.00833884	.1809259	.2149402	.14847	.30989

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

gumminessMWIR

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.061	7	.009	25.155	.000
Within Groups	.008	24	.000		
Total	.069	31			

gumminessMWIR

Duncan[a]

caketypeMWIR	N	Subset for alpha = .05		
		1	2	3
8	4	.1632392		
7	4	.1633956		
3	4	.1656312		
5	4	.1672528		
2	4	.1821068		
4	4		.2214498	
1	4		.2267371	
6	4			.2936520
Sig.		.210	.691	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.8 ANOVA and Duncan Single Range Test Table for springiness of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

springiness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	4.2594005	.04026070	.02846862	3.8976724	4.6211286	4.23093	4.28787
2	2	4.0700005	.25471408	.18011005	1.7814853	6.3585157	3.88989	4.25011
3	2	3.8610003	.71780293	.50756332	-2.5882032	10.3102037	3.35344	4.36856
4	2	4.2176093	.04596377	.03250129	3.8046412	4.6305774	4.18511	4.25011
5	2	3.8440605	.69384650	.49062356	-2.3899029	10.0780240	3.35344	4.33468
6	2	4.2122210	.03834363	.02711304	3.8677172	4.5567248	4.18511	4.23933
7	2	4.3631640	.04027670	.02847993	4.0012922	4.7250358	4.33468	4.39164
8	2	4.0020617	.06215827	.04395253	3.4435918	4.5605316	3.95811	4.04601
Total	16	4.1036897	.32459506	.08114876	3.9307252	4.2766542	3.35344	4.39164

Cake types: 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

ANOVA

springiness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.508	7	.073	.542	.783
Within Groups	1.072	8	.134		
Total	1.580	15			

springiness

Duncan[a]

caketype	N	Subset for alpha = .05 1
5	2	3.8440605
3	2	3.8610003
8	2	4.0020617
2	2	4.0700005
6	2	4.2122210
4	2	4.2176093
1	2	4.2594005
7	2	4.3631640
Sig.		.222

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.9 ANOVA and Duncan Single Range Test Table for chewiness of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

chewiness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	.7607041	.08139035	.05755167	.0294408	1.4919674	.70315	.81826
2	2	.5915055	.06887941	.04870510	-.0273514	1.2103624	.54280	.64021
3	2	.5412117	.02287196	.01617292	.3357153	.7467081	.52504	.55738
4	2	.7323051	.13024129	.09209450	-.4378664	1.9024766	.64021	.82440
5	2	.5613755	.05138793	.03633675	.0996734	1.0230777	.52504	.59771
6	2	.8851166	.08586679	.06071699	.1136341	1.6565991	.82440	.94583
7	2	.5869264	.01525350	.01078585	.4498792	.7239737	.57614	.59771
8	2	.5130388	.02059994	.01456636	.3279556	.6981219	.49847	.52761
Total	16	.6465230	.13653953	.03413488	.5737662	.7192797	.49847	.94583

Cake types: 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

ANOVA

chewiness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.240	7	.034	6.943	.007
Within Groups	.040	8	.005		
Total	.280	15			

Table A.9 Continued

chewiness

Duncan[a]

caketype	N	Subset for alpha = .05		
		1	2	3
8	2	.5130388		
3	2	.5412117		
5	2	.5613755	.5613755	
7	2	.5869264	.5869264	
2	2	.5915055	.5915055	
4	2		.7323051	.7323051
1	2			.7607041
6	2			.8851166
Sig.		.327	.052	.070

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.10 ANOVA and Duncan Single Range Test Table for gumminess of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

gumminessCONV

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
9	4	.2052278	.03149020	.01574510	.1551198	.2553357	.16226	.23341
10	4	.1730140	.02417376	.01208688	.1345482	.2114799	.15003	.20120
11	4	.1360095	.01381570	.00690785	.1140257	.1579934	.12416	.15597
12	4	.2105047	.03252084	.01626042	.1587568	.2622526	.16226	.23341
13	4	.1325622	.01379295	.00689648	.1106145	.1545099	.11631	.15003
14	4	.2584535	.01104432	.00552216	.2408795	.2760274	.24304	.26824
15	4	.1384470	.01477346	.00738673	.1149391	.1619548	.12800	.15967
16	4	.1302019	.01009534	.00504767	.1141380	.1462659	.11631	.13965
Total	32	.1730526	.04868497	.00860637	.1554998	.1906054	.11631	.26824

Cake types: 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

Table A.10 Continued

ANOVA

gumminessCONV

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.063	7	.009	20.863	.000
Within Groups	.010	24	.000		
Total	.073	31			

gumminessCONV

Duncan[a]

		Subset for alpha = .05			
caketypeCONV	N	1	2	3	4
16	4	.1302019			
13	4	.1325622			
11	4	.1360095			
15	4	.1384470			
10	4		.1730140		
9	4			.2052278	
12	4			.2105047	
14	4				.2584535
Sig.		.614	1.000	.723	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.11 ANOVA and Duncan Single Range Test Table for ΔE of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

deltaE

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	28.69591	.99170950	.70124452	19.7857503	37.6060631	27.99466	29.39715
2	2	28.59185	.14695746	.10391462	27.2714903	29.9122110	28.48794	28.69577
3	2	28.55179	.10451838	.07390566	27.6127314	29.4908522	28.47789	28.62570
4	2	29.69938	2.43990977	1.725277	7.7776623	51.6211014	27.97411	31.42466
5	2	28.60594	1.50340216	1.063066	15.0984090	42.1134741	27.54288	29.66901
6	2	27.95698	1.31305154	.92846765	16.1596813	39.7542815	27.02851	28.88545
7	2	27.95698	1.31305154	.92846765	16.1596813	39.7542815	27.02851	28.88545
8	2	28.31689	.34347194	.24287134	25.2309177	31.4028635	28.07402	28.55976
9	2	10.03438	.67483319	.47717912	3.9712397	16.0975110	9.55720	10.51155
10	2	10.55060	.13973776	.09880952	9.2951097	11.8060975	10.45179	10.64941
11	2	10.36796	.18927714	.13383915	8.6673720	12.0685473	10.23412	10.50180
12	2	10.86602	.52840939	.37364187	6.1184500	15.6135901	10.49238	11.23966
13	2	10.67519	2.35808423	1.667417	-10.5113545	31.8617380	9.00777	12.34261
14	2	10.80032	.23667726	.16735610	8.6738629	12.9267845	10.63297	10.96768
15	2	10.29199	.29955183	.21181513	7.6006273	12.9833601	10.08018	10.50381
16	2	10.23088	.24121118	.17056206	8.0636837	12.3980766	10.06032	10.40144
Total	32	19.51207	9.22287949	1.630390	16.1868645	22.8372698	9.00777	31.42466

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 0.6% guar gum containing cake baked in MW-IR combination oven, 5: 0.6% xanthan gum containing cake baked in MW-IR combination oven, 6: 1% guar gum containing cake baked in MW-IR combination oven, 7: 1% xanthan gum containing cake baked in MW-IR combination oven, 8: Gum blend containing cake baked in MW-IR combination oven, 9: Control cake baked in conventional oven, 10: 0.3% guar gum containing cake baked in conventional oven, 11: 0.3% xanthan containing cake baked in conventional oven, 12: 0.6% guar gum containing cake baked in conventional oven, 13: 0.6% xanthan gum containing cake baked in conventional oven, 14: 1% guar gum containing cake baked in conventional oven, 15: 1% xanthan gum containing cake baked conventional oven, 16: Gum blend containing cake baked in conventional oven.

Table A.11 Continued

ANOVA

deltaE

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2617.557	15	174.504	144.292	.000
Within Groups	19.350	16	1.209		
Total	2636.907	31			

deltaE

Duncan[a]

		Subset for alpha = .05	
caketype	N	1	2
9	2	10.03438	
16	2	10.23088	
15	2	10.29199	
11	2	10.36796	
10	2	10.55060	
13	2	10.67519	
14	2	10.80032	
12	2	10.86602	
6	2		27.95698
7	2		27.95698
8	2		28.31689
3	2		28.55179
2	2		28.59185
5	2		28.60594
1	2		28.69591
4	2		29.69938
Sig.		.511	.181

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.12 ANOVA and Duncan Single Range Test Table for texture of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

texture

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	11	1.73	.647	.195	1.29	2.16	1	3
2	11	4.45	.522	.157	4.10	4.81	4	5
3	11	2.27	.647	.195	1.84	2.71	1	3
4	11	4.45	.522	.157	4.10	4.81	4	5
Total	44	3.23	1.379	.208	2.81	3.65	1	5

Cake types: 1: Control cake baked in MW-IR combination oven, 2: Cake containing gum blend baked in MW-IR combination oven, 3: Control cake baked in conventional oven, 4: Cake containing gum blend baked in conventional oven

ANOVA

texture

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	67.909	3	22.636	65.526	.000
Within Groups	13.818	40	.345		
Total	81.727	43			

texture

Duncan[a]

caketype	N	Subset for alpha = .05		
		1	2	3
1	11	1.73		
3	11		2.27	
2	11			4.45
4	11			4.45
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 11.000.

Table A.13 ANOVA and Duncan Single Range Test Table for taste of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

taste

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	11	1.64	.809	.244	1.09	2.18	1	3
2	11	4.27	.647	.195	3.84	4.71	3	5
3	11	2.45	.688	.207	1.99	2.92	1	3
4	11	4.45	.688	.207	3.99	4.92	3	5
Total	44	3.20	1.391	.210	2.78	3.63	1	5

Cake types: 1: Control cake baked in MW-IR combination oven, 2: Cake containing gum blend baked in MW-IR combination oven, 3: Control cake baked in conventional oven, 4: Cake containing gum blend baked in conventional oven

ANOVA

taste

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	62.977	3	20.992	41.607	.000
Within Groups	20.182	40	.505		
Total	83.159	43			

taste

Duncan[a]

caketype	N	Subset for alpha = .05		
		1	2	3
1	11	1.64		
3	11		2.45	
2	11			4.27
4	11			4.45
Sig.		1.000	1.000	.552

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 11.000.

Table A.14 ANOVA and Duncan Single Range Test Table for peak viscosity of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

PEAK

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	104.0000	.00000000	.00000000	104.0000000	104.0000000	104.0000	104.0000
2	2	145.5000	2.12132034	1.500000	126.4406929	164.5593071	144.0000	147.0000
3	2	161.0000	8.48528137	6.000000	84.7627716	237.2372284	155.0000	167.0000
4	2	169.5000	.70710678	.50000000	163.1468976	175.8531024	169.0000	170.0000
5	2	215.0000	21.21320344	15.00000	24.4069290	405.5930710	200.0000	230.0000
6	2	190.0000	14.14213562	10.00000	62.9379526	317.0620474	180.0000	200.0000
Total	12	164.1667	37.22617196	10.74627	140.5142854	187.8190479	104.0000	230.0000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 5: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

PEAK

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14516.667	5	2903.333	23.961	.001
Within Groups	727.000	6	121.167		
Total	15243.667	11			

Table A.14 Continued

PEAK

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
1	2	104.0000			
2	2		145.5000		
3	2		161.0000		
4	2		169.5000	169.5000	
6	2			190.0000	190.0000
5	2				215.0000
Sig.		1.000	.080	.112	.064

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.15 ANOVA and Duncan Single Range Test Table for trough viscosity of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

TROUGH

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	87.50000	2.12132034	1.500000	68.4406929	106.5593071	86.00000	89.00000
2	2	125.0000	7.07106781	5.000000	61.4689763	188.5310237	120.0000	130.0000
3	2	132.5000	4.94974747	3.500000	88.0282834	176.9717166	129.0000	136.0000
4	2	144.5000	12.02081528	8.500000	36.4972597	252.5027403	136.0000	153.0000
5	2	180.0000	24.04163056	17.00000	-36.0054805	396.0054805	163.0000	197.0000
6	2	164.5000	13.43502884	9.500000	43.7910550	285.2089450	155.0000	174.0000
Total	12	139.0000	32.31380229	9.328191	118.4687895	159.5312105	86.00000	197.0000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 5: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven.

Table A.15 Continued

ANOVA

TROUGH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10504.000	5	2100.800	12.836	.004
Within Groups	982.000	6	163.667		
Total	11486.000	11			

TROUGH

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
1	2	87.50000			
2	2		125.0000		
3	2		132.5000	132.5000	
4	2		144.5000	144.5000	
6	2			164.5000	164.5000
5	2				180.0000
Sig.		1.000	.191	.052	.271

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.16 ANOVA and Duncan Single Range Test Table for breakdown viscosity of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

BREAKDOWN

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	16.50000	2.12132034	1.500000	-2.5593071	35.5593071	15.00000	18.00000
2	2	20.50000	4.94974747	3.500000	-23.9717166	64.9717166	17.00000	24.00000
3	2	28.50000	3.53553391	2.500000	-3.2655118	60.2655118	26.00000	31.00000
4	2	25.00000	12.72792206	9.000000	-89.3558426	139.3558426	16.00000	34.00000
5	2	35.00000	2.82842712	2.000000	9.5875905	60.4124095	33.00000	37.00000
6	2	25.50000	.70710678	.50000000	19.1468976	31.8531024	25.00000	26.00000
Total	12	25.16667	7.51765599	2.170160	20.3901759	29.9431574	15.00000	37.00000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 5: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

BREAKDOWN

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	409.667	5	81.933	2.319	.168
Within Groups	212.000	6	35.333		
Total	621.667	11			

BREAKDOWN

Duncan[a]

caketype	N	Subset for alpha = .05 1	Subset for alpha = .05 2
1	2	16.50000	
2	2	20.50000	20.50000
4	2	25.00000	25.00000
6	2	25.50000	25.50000
3	2	28.50000	28.50000
5	2		35.00000
Sig.		.105	.061

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.17 ANOVA and Duncan Single Range Test Table for final viscosity of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

FINALVISCOSITY

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	163.5000	6.36396103	4.500000	106.3220787	220.6779213	159.0000	168.0000
2	2	228.0000	.00000000	.00000000	228.0000000	228.0000000	228.0000	228.0000
3	2	251.0000	11.31370850	8.000000	149.3503621	352.6496379	243.0000	259.0000
4	2	260.5000	17.67766953	12.50000	101.6724408	419.3275592	248.0000	273.0000
5	2	297.5000	23.33452378	16.50000	87.8476219	507.1523781	281.0000	314.0000
6	2	275.5000	20.50609665	14.50000	91.2600313	459.7399687	261.0000	290.0000
Total	12	246.0000	45.94660933	13.26364	216.8069172	275.1930828	159.0000	314.0000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 5: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven.

ANOVA

FINALVISCOSITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21776.000	5	4355.200	18.071	.001
Within Groups	1446.000	6	241.000		
Total	23222.000	11			

Table A.17 Continued

FINALVISCOSITY

Duncan[a]

caketype	N	Subset for alpha = .05 1	2	3	4
1	2	163.5000			
2	2		228.0000		
3	2		251.0000	251.0000	
4	2		260.5000	260.5000	260.5000
6	2			275.5000	275.5000
5	2				297.5000
Sig.		1.000	.090	.178	.061

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.18 ANOVA and Duncan Single Range Test Table for setback viscosity of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

SETBACK

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	Upper Bound	Minimum	Maximum
1	2	76.00000	8.48528137	6.000000	-.2372284	152.2372284	70.00000	82.00000
2	2	103.0000	7.07106781	5.000000	39.4689763	166.5310237	98.00000	108.0000
3	2	118.5000	6.36396103	4.500000	61.3220787	175.6779213	114.0000	123.0000
4	2	116.0000	5.65685425	4.000000	65.1751811	166.8248189	112.0000	120.0000
5	2	117.5000	.70710678	.50000000	111.1468976	123.8531024	117.0000	118.0000
6	2	111.0000	7.07106781	5.000000	47.4689763	174.5310237	106.0000	116.0000
Total	12	107.0000	16.17517739	4.669372	96.7227826	117.2772174	70.00000	123.0000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 5: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven.

Table A.18 Continued

ANOVA

SETBACK

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2633.000	5	526.600	12.896	.004
Within Groups	245.000	6	40.833		
Total	2878.000	11			

SETBACK

Duncan[a]

		Subset for alpha = .05	
caketype	N	1	2
1	2	76.00000	
2	2		103.0000
6	2		111.0000
4	2		116.0000
5	2		117.5000
3	2		118.5000
Sig.		1.000	.062

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.19 ANOVA and Duncan Single Range Test Table for peak viscosity of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

PEAK

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	119.5000	4.94974747	3.500000	75.0282834	163.9717166	116.0000	123.0000
2	2	151.0000	14.14213562	10.00000	23.9379526	278.0620474	141.0000	161.0000
3	2	144.0000	1.41421356	1.000000	131.2937953	156.7062047	143.0000	145.0000
4	2	160.0000	1.41421356	1.000000	147.2937953	172.7062047	159.0000	161.0000
5	2	210.0000	2.82842712	2.000000	184.5875905	235.4124095	208.0000	212.0000
6	2	233.5000	13.43502884	9.500000	112.7910550	354.2089450	224.0000	243.0000
Total	12	169.6667	41.62021653	12.01472	143.2224427	196.1108906	116.0000	243.0000

Cake types: 1: Control cake baked in conventional oven, 2: 0.3% guar gum containing cake baked in conventional oven, 3: 0.3% xanthan containing cake baked in conventional oven, 4: 1% guar gum containing cake baked in conventional oven, 5: 1% xanthan gum containing cake baked conventional oven, 6: Gum blend containing cake baked in conventional oven.

ANOVA

PEAK

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	18637.667	5	3727.533	53.634	.000
Within Groups	417.000	6	69.500		
Total	19054.667	11			

PEAK

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
1	2	119.5000			
3	2		144.0000		
2	2		151.0000		
4	2		160.0000		
5	2			210.0000	
6	2				233.5000
Sig.		1.000	.113	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.20 ANOVA and Duncan Single Range Test Table for trough viscosity of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

TROUGH

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	93.50000	9.19238816	6.500000	10.9096692	176.0903308	87.00000	100.0000
2	2	125.0000	9.89949494	7.000000	36.0565668	213.9434332	118.0000	132.0000
3	2	117.0000	.00000000	.00000000	117.0000000	117.0000000	117.0000	117.0000
4	2	134.5000	.70710678	.50000000	128.1468976	140.8531024	134.0000	135.0000
5	2	181.0000	2.82842712	2.000000	155.5875905	206.4124095	179.0000	183.0000
6	2	191.0000	4.24264069	3.000000	152.8813858	229.1186142	188.0000	194.0000
Total	12	140.3333	36.51234743	10.54021	117.1344946	163.5321721	87.00000	194.0000

Cake types: 1: Control cake baked in conventional oven, 2: 0.3% guar gum containing cake baked in conventional oven, 3: 0.3% xanthan containing cake baked in conventional oven, 4: 1% guar gum containing cake baked in conventional oven, 5: 1% xanthan gum containing cake baked conventional oven, 6: Gum blend containing cake baked in conventional oven.

ANOVA

TROUGH

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14455.667	5	2891.133	82.999	.000
Within Groups	209.000	6	34.833		
Total	14664.667	11			

Table A.20 Continued

TROUGH

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
1	2	93.50000			
3	2		117.0000		
2	2		125.0000	125.0000	
4	2			134.5000	
5	2				181.0000
6	2				191.0000
Sig.		1.000	.224	.159	.141

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.21 ANOVA and Duncan Single Range Test Table for breakdown viscosity of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

BREAKDOWN

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	26.00000	4.24264069	3.000000	-12.1186142	64.1186142	23.00000	29.00000
2	2	26.00000	4.24264069	3.000000	-12.1186142	64.1186142	23.00000	29.00000
3	2	27.00000	1.41421356	1.000000	14.2937953	39.7062047	26.00000	28.00000
4	2	25.50000	.70710678	.50000000	19.1468976	31.8531024	25.00000	26.00000
5	2	29.00000	.00000000	.00000000	29.0000000	29.0000000	29.00000	29.00000
6	2	42.50000	9.19238816	6.500000	-40.0903308	125.0903308	36.00000	49.00000
Total	12	29.33333	7.10100292	2.049883	24.8215713	33.8450953	23.00000	49.00000

Cake types: 1: Control cake baked in conventional oven, 2: 0.3% guar gum containing cake baked in conventional oven, 3: 0.3% xanthan containing cake baked in conventional oven, 4: 1% guar gum containing cake baked in conventional oven, 5: 1% xanthan gum containing cake baked conventional oven, 6: Gum blend containing cake baked in conventional oven.

Table A.21 Continued

ANOVA

BREAKDOWN

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	431.667	5	86.333	4.211	.055
Within Groups	123.000	6	20.500		
Total	554.667	11			

BREAKDOWN

Duncan[a]

caketype	N	Subset for alpha = .05	
		1	2
4	2	25.50000	
1	2	26.00000	
2	2	26.00000	
3	2	27.00000	
5	2	29.00000	
6	2		42.50000
Sig.		.485	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.22 ANOVA and Duncan Single Range Test Table for final viscosity of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

FINALVISCOSITY

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	186.0000	12.72792206	9.000000	71.6441574	300.3558426	177.0000	195.0000
2	2	234.5000	9.19238816	6.500000	151.9096692	317.0903308	228.0000	241.0000
3	2	219.5000	3.53553391	2.500000	187.7344882	251.2655118	217.0000	222.0000
4	2	259.0000	11.31370850	8.000000	157.3503621	360.6496379	251.0000	267.0000
5	2	302.0000	4.24264069	3.000000	263.8813858	340.1186142	299.0000	305.0000
6	2	318.0000	2.82842712	2.000000	292.5875905	343.4124095	316.0000	320.0000
Total	12	253.1667	48.28294134	13.93808	222.4891493	283.8441840	177.0000	320.0000

Cake types: 1: Control cake baked in conventional oven, 2: 0.3% guar gum containing cake baked in conventional oven, 3: 0.3% xanthan containing cake baked in conventional oven, 4: 1% guar gum containing cake baked in conventional oven, 5: 1% xanthan gum containing cake baked conventional oven, 6: Gum blend containing cake baked in conventional oven.

ANOVA

FINALVISCOSITY

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	25230.667	5	5046.133	73.309	.000
Within Groups	413.000	6	68.833		
Total	25643.667	11			

FINALVISCOSITY

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
1	2	186.0000			
3	2		219.5000		
2	2		234.5000		
4	2			259.0000	
5	2				302.0000
6	2				318.0000
Sig.		1.000	.121	1.000	.102

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.23 ANOVA and Duncan Single Range Test Table for setback viscosity of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

SETBACK

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	92.50000	3.53553391	2.500000	60.7344882	124.2655118	90.00000	95.00000
2	2	109.5000	.70710678	.50000000	103.1468976	115.8531024	109.0000	110.0000
3	2	102.5000	3.53553391	2.500000	70.7344882	134.2655118	100.0000	105.0000
4	2	124.5000	12.02081528	8.500000	16.4972597	232.5027403	116.0000	133.0000
5	2	121.0000	7.07106781	5.000000	57.4689763	184.5310237	116.0000	126.0000
6	2	127.0000	1.41421356	1.000000	114.2937953	139.7062047	126.0000	128.0000
Total	12	112.8333	13.78954369	3.980698	104.0718753	121.5947914	90.00000	133.0000

Cake types: 1: Control cake baked in conventional oven, 2: 0.3% guar gum containing cake baked in conventional oven, 3: 0.3% xanthan containing cake baked in conventional oven, 4: 1% guar gum containing cake baked in conventional oven, 5: 1% xanthan gum containing cake baked conventional oven, 6: Gum blend containing cake baked in conventional oven.

ANOVA

SETBACK

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1869.667	5	373.933	10.106	.007
Within Groups	222.000	6	37.000		
Total	2091.667	11			

Table A.23 Continued

SETBACK

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
1	2	92.50000			
3	2	102.5000	102.5000		
2	2		109.5000	109.5000	
5	2			121.0000	121.0000
4	2			124.5000	124.5000
6	2				127.0000
Sig.		.151	.294	.055	.376

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.24 ANOVA and Duncan Single Range Test Table for gelatinization degree of cakes formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

geldegree

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	4	79.6133	1.27393	.63696	77.5862	81.6404	78.68	81.39
2	4	79.0319	.84293	.42146	77.6906	80.3732	78.57	80.30
3	4	78.7677	.41323	.20661	78.1102	79.4252	78.36	79.33
4	4	76.6080	.92097	.46048	75.1425	78.0734	75.45	77.69
5	4	76.6782	1.50940	.75470	74.2764	79.0799	75.48	78.81
6	4	76.6923	1.05430	.52715	75.0147	78.3699	75.38	77.86
Total	24	77.8986	1.59601	.32578	77.2246	78.5725	75.38	81.39

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 5: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven.

Table A.24 Continued

ANOVA

geldegree

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	38.360	5	7.672	6.828	.001
Within Groups	20.227	18	1.124		
Total	58.587	23			

geldegree

Duncan[a]

caketype	N	Subset for alpha = .05	
		1	2
4	4	76.6080	
5	4	76.6782	
6	4	76.6923	
3	4		78.7677
2	4		79.0319
1	4		79.6133
Sig.		.917	.300

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.25 ANOVA and Duncan Single Range Test Table for gelatinization degree of cakes formulated with different gums and gum concentrations baked in conventional oven

Descriptives

geldegree

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
7	4	79.7617	1.15722	.57861	77.9203	81.6031	78.69	80.94
8	4	77.4917	3.11549	1.55775	72.5342	82.4491	74.23	81.50
9	4	77.7232	2.01339	1.00669	74.5195	80.9270	75.12	79.83
10	4	76.5082	2.06619	1.03310	73.2204	79.7960	74.13	79.17
11	4	75.5660	2.45032	1.22516	71.6669	79.4650	73.37	79.00
12	4	75.1792	1.56071	.78035	72.6958	77.6626	73.54	76.95
Total	24	77.0383	2.46198	.50255	75.9987	78.0779	73.37	81.50

Cake types: 7: Control cake baked in conventional oven, 8: 0.3% guar gum containing cake baked in conventional oven, 9: 0.3% xanthan containing cake baked in conventional oven, 10: 1% guar gum containing cake baked in conventional oven, 11: 1% xanthan gum containing cake baked conventional oven, 12: Gum blend containing cake baked in conventional oven.

ANOVA

geldegree

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	55.986	5	11.197	2.416	.076
Within Groups	83.425	18	4.635		
Total	139.411	23			

geldegree

Duncan[a]

caketype	N	Subset for alpha = .05	
		1	2
12	4	75.1792	
11	4	75.5660	
10	4	76.5082	76.5082
8	4	77.4917	77.4917
9	4	77.7232	77.7232
7	4		79.7617
Sig.		.149	.064

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.26 ANOVA and Duncan Single Range Test Table for weight loss of cakes during storage formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

H24

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	.8430233	.04111086	.02906977	.4736568	1.2123897	.81395	.87209
2	2	.8410673	.04101547	.02900232	.4725579	1.2095767	.81206	.87007
3	2	.8381503	.04087322	.02890173	.4709189	1.2053816	.80925	.86705
4	2	.8362168	.04077894	.02883506	.4698326	1.2026011	.80738	.86505
5	2	.7192175	.04068509	.02876870	.3536765	1.0847585	.69045	.74799
6	2	.7183908	.04063832	.02873563	.3532700	1.0835116	.68966	.74713
7	2	.8967391	.03842972	.02717391	.5514618	1.2420164	.86957	.92391
8	2	.8870968	.03801649	.02688172	.5455321	1.2286614	.86022	.91398
9	2	.8823529	.03781320	.02673797	.5426148	1.2220910	.85561	.90909
10	2	.8244681	.03761206	.02659575	.4865371	1.1623991	.79787	.85106
11	2	.7696391	.03753221	.02653928	.4324256	1.1068526	.74310	.79618
12	2	.7688229	.03749241	.02651113	.4319670	1.1056788	.74231	.79533
Total	24	.8187654	.06645065	.01356418	.7907058	.8468251	.68966	.92391

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 6: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven, 7: Control cake baked in conventional oven, 8: 0.3% guar gum containing cake baked in conventional oven, 9: 0.3% xanthan containing cake baked in conventional oven, 10: 1% guar gum containing cake baked in conventional oven, 11: 1% xanthan gum containing cake baked conventional oven, 12: Gum blend containing cake baked in conventional oven.

ANOVA

H24

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.083	11	.008	4.868	.006
Within Groups	.019	12	.002		
Total	.102	23			

Table A.26 Continued

H24

Duncan[a]

CAKETYPE	N	Subset for alpha = .05		
		1	2	3
6	2	.7183908		
5	2	.7192175		
12	2	.7688229	.7688229	
11	2	.7696391	.7696391	
10	2		.8244681	.8244681
4	2		.8362168	.8362168
3	2		.8381503	.8381503
2	2		.8410673	.8410673
1	2		.8430233	.8430233
9	2			.8823529
8	2			.8870968
7	2			.8967391
Sig.		.250	.116	.126

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.27 ANOVA and Duncan Single Range Test Table for hardness of cakes during storage formulated with different gums and gum concentrations baked in MW-IR combination oven

Descriptives

hardness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
1	2	.3777450	.00282418	.00199700	.3523707	.4031193	.37575	.37974
2	2	.3318590	.05030782	.03557300	-.1201388	.7838568	.29629	.36743
3	2	.2628805	.02428983	.01717550	.0446451	.4811159	.24571	.28006
4	2	.4201610	.02171949	.01535800	.2250191	.6153029	.40480	.43552
5	2	.2853785	.00172746	.00122150	.2698579	.3008991	.28416	.28660
6	2	.2572235	.01223365	.00865050	.1473085	.3671385	.24857	.26587
7	2	.4011600	.01645579	.01163600	.2533106	.5490094	.38952	.41280
8	2	.4222685	.05584941	.03949150	-.0795186	.9240556	.38278	.46176
9	2	.4835755	.03050812	.02157250	.2094709	.7576801	.46200	.50515
10	2	.6155370	.08784105	.06211300	-.1736835	1.4047575	.55342	.67765
11	2	.4027160	.00411819	.00291200	.3657155	.4397165	.39980	.40563
12	2	.3935250	.06627853	.04686600	-.2019640	.9890140	.34666	.44039
13	2	.4914995	.08348598	.05903350	-.2585922	1.2415912	.43247	.55053
14	2	.5980105	.06176083	.04367150	.0431115	1.1529095	.55434	.64168
15	2	.4973275	.01636599	.01157250	.3502849	.6443701	.48576	.50890
16	2	.6737135	.00295076	.00208650	.6472020	.7002250	.67163	.67580
17	2	.5773965	.00808011	.00571350	.5047996	.6499934	.57168	.58311
18	2	.4634565	.03261954	.02306550	.1703815	.7565315	.44039	.48652
19	2	.5674450	.00630174	.00445600	.5108262	.6240638	.56299	.57190
20	2	.6684175	.00952544	.00673550	.5828349	.7540001	.66168	.67515
21	2	.5906660	.06503685	.04598800	.0063331	1.1749989	.54468	.63665
22	2	.7176895	.01008829	.00713350	.6270498	.8083292	.71056	.72482
23	2	.6296360	.06257329	.04424600	.0674373	1.1918347	.58539	.67388
24	2	.5609035	.06004397	.04245750	.0214298	1.1003772	.51845	.60336
25	2	.6234605	.10313506	.07292750	-.3031712	1.5500922	.55053	.69639
26	2	.7141605	.04725382	.03341350	.2896017	1.1387193	.68075	.74757
27	2	.6540630	.03105472	.02195900	.3750475	.9330785	.63210	.67602
28	2	.7781715	.03059580	.02163450	.5032791	1.0530639	.75654	.79981
29	2	.6491070	.02518290	.01780700	.4228476	.8753664	.63130	.66691
30	2	.5825280	.05622630	.03975800	.0773547	1.0877013	.54277	.62229
31	2	.7562425	.02034700	.01438750	.5734320	.9390530	.74186	.77063
32	2	.7348545	.01460529	.01032750	.6036312	.8660778	.72453	.74518
33	2	.7043980	.05572850	.03940600	.2036973	1.2050987	.66499	.74380
34	2	.8358665	.03803740	.02689650	.4941141	1.1776189	.80897	.86276
35	2	.6516110	.02330624	.01648000	.4422127	.8610093	.63513	.66809
36	2	.5893350	.04890209	.03457900	.1499671	1.0287029	.55476	.62391
Total	72	.5545553	.15412550	.01816386	.5183375	.5907730	.24571	.86276

Cake types: (All the cakes are baked in MW-IR combination oven) 1: Control cake, 2: 0.3% guar gum containing cake, 3: 0.3% xanthan containing cake, 4: 1% guar gum containing cake, 5: 1% xanthan gum containing cake, 6: Gum blend containing cake, 7: Control cake stored for 24 h, 8: Cake containing 0.3% guar gum stored for 24 h, 9: 0.3% xanthan containing cake stored for 24 h, 10: 1% guar gum containing cake stored for 24 h, 11: 1% xanthan gum containing cake stored for 24 h, 12: Gum blend containing cake stored for 24 h, 13: Control cake stored for 48 h, 14: Cake containing 0.3% guar gum stored for 48 h, 15: 0.3% xanthan containing cake stored for 48 h, 16: 1% guar gum containing cake stored for 48 h, 17: 1% xanthan gum containing cake stored for 48 h, 18: Gum blend containing cake stored for 48 h, 19: Control cake stored for 72 h, 20: Cake containing 0.3% guar gum stored for 72 h, 21: 0.3% xanthan containing cake stored for 72 h, 22: 1% guar gum containing cake stored for 72 h, 23: 1% xanthan gum containing stored for 72 h, 24: Gum blend containing cake stored for 72 h, 25: Control cake stored for 96 h, 26: Cake containing 0.3% guar gum stored for 96 h, 27: 0.3% xanthan containing cake stored for 96 h, 28: 1% guar gum containing cake stored for 96 h, 29: 1% xanthan gum containing cake stored for 96 h, 30: Gum blend containing cake stored for 96 h, 31: Control cake stored for 120 h, 32: 0.3% guar gum containing cake stored for 120 h, 33: 0.3% xanthan containing cake stored for 120 h, 34: 1% guar gum containing cake stored for 120 h, 35: 1% xanthan gum containing cake stored for 120 h, 36: Gum blend containing cake stored for 120 h.

ANOVA

hardness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.616	35	.046	23.387	.000
Within Groups	.071	36	.002		
Total	1.687	71			

hardness

Duncan[a]

caketype	N	Subset for alpha = .05															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
6	2	.2572235															
3	2	.2628805															
5	2	.2853785	.2853785														
2	2	.3318590	.3318590	.3318590													
1	2		.3777450	.3777450	.3777450												
12	2			.3935250	.3935250	.3935250											
7	2			.4011600	.4011600	.4011600											
11	2			.4027160	.4027160	.4027160											
4	2			.4201610	.4201610	.4201610											
8	2			.4222685	.4222685	.4222685											
18	2				.4634565	.4634565	.4634565										
9	2					.4835755	.4835755	.4835755									
13	2					.4914995	.4914995	.4914995	.4914995								
15	2					.4973275	.4973275	.4973275	.4973275	.4973275							
24	2						.5609035	.5609035	.5609035	.5609035	.5609035						
19	2							.5674450	.5674450	.5674450	.5674450	.5674450					
17	2							.5773965	.5773965	.5773965	.5773965	.5773965					
30	2							.5825280	.5825280	.5825280	.5825280	.5825280					
36	2								.5893350	.5893350	.5893350	.5893350					
21	2								.5906660	.5906660	.5906660	.5906660					
14	2									.5980105	.5980105	.5980105					
10	2										.6155370	.6155370	.6155370				
25	2										.6234605	.6234605	.6234605				
23	2										.6296360	.6296360	.6296360	.6296360			
29	2										.6491070	.6491070	.6491070	.6491070			
35	2										.6516110	.6516110	.6516110	.6516110	.6516110		
27	2										.6540630	.6540630	.6540630	.6540630	.6540630		
20	2											.6684175	.6684175	.6684175	.6684175		
16	2											.6737135	.6737135	.6737135	.6737135		
33	2												.7043980	.7043980	.7043980	.7043980	
26	2												.7141605	.7141605	.7141605	.7141605	
22	2												.7176895	.7176895	.7176895	.7176895	
32	2													.7348545	.7348545	.7348545	
31	2														.7562425	.7562425	.7562425
28	2															.7781715	.7781715
34	2																.8358665
Sig.		.133	.056	.085	.102	.052	.056	.059	.061	.057	.087	.053	.059	.051	.050	.154	.098

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.28 ANOVA and Duncan Single Range Test Table for hardness of cakes during storage formulated with different gums and gum concentrations baked conventional oven

Descriptives

hardness

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	.3565535	.05590174	.03952850	-.1457037	.8588107	.31703	.39608
2	2	.3004230	.01530038	.01081900	.1629546	.4378914	.28960	.31124
3	2	.3305740	.00450427	.00318500	.2901047	.3710433	.32739	.33376
4	2	.4234710	.02977627	.02105500	.1559419	.6910001	.40242	.44453
5	2	.2555065	.00296207	.00209450	.2288934	.2821196	.25341	.25760
6	2	.2412690	.01640063	.01159700	.0939151	.3886229	.22967	.25287
7	2	.3813380	.04326504	.03059300	-.0073829	.7700589	.35075	.41193
8	2	.4339055	.02056196	.01453950	.2491636	.6186474	.41937	.44845
9	2	.3315940	.01519431	.01074400	.1950785	.4681095	.32085	.34234
10	2	.5537285	.00397606	.00281150	.5180050	.5894520	.55092	.55654
11	2	.2857050	.01586182	.01121600	.1431922	.4282178	.27449	.29692
12	2	.2973825	.02496158	.01765050	.0731116	.5216534	.27973	.31503
13	2	.4079345	.08197701	.05796650	-.3285997	1.1444687	.34997	.46590
14	2	.4715520	.00206192	.00145800	.4530264	.4900776	.47009	.47301
15	2	.3708755	.03909381	.02764350	.0196315	.7221195	.34323	.39852
16	2	.6213460	.02102370	.01486600	.4324556	.8102364	.60648	.63621
17	2	.2919210	.00707107	.00500000	.2283900	.3554520	.28692	.29692
18	2	.3682815	.01292096	.00913650	.2521913	.4843717	.35915	.37742
19	2	.4377480	.06831924	.04830900	-.1760760	1.0515720	.38944	.48606
20	2	.5821335	.03861864	.02730750	.2351588	.9291082	.55483	.60944
21	2	.4650810	.06255915	.04423600	-.0969907	1.0271527	.42085	.50932
22	2	.6639360	.03920766	.02772400	.3116692	1.0162028	.63621	.69166
23	2	.3037000	.00958695	.00677900	.2175646	.3898354	.29692	.31048
24	2	.3900875	.01791738	.01266950	.2291062	.5510688	.37742	.40276
25	2	.5174415	.01441579	.01019350	.3879208	.6469622	.50725	.52764
26	2	.6505100	.03646408	.02578400	.3228932	.9781268	.62473	.67629
27	2	.5549270	.01146362	.00810600	.4519305	.6579235	.54682	.56303
28	2	.6896940	.01136179	.00803400	.5876124	.7917756	.68166	.69773
29	2	.3871220	.06201751	.04385300	-.1700832	.9443272	.34327	.43098
30	2	.4142055	.01619062	.01144850	.2687385	.5596725	.40276	.42565
31	2	.6922235	.06045268	.04274650	.1490777	1.2353693	.64948	.73497
32	2	.6779175	.03090127	.02185050	.4002806	.9555544	.65607	.69977
33	2	.5748135	.06514221	.04606250	-.0104661	1.1600931	.52875	.62088
34	2	.6979845	.05592578	.03954550	.1955113	1.2004577	.65844	.73753
35	2	.4651690	.04835762	.03419400	.0306930	.8996450	.43098	.49936
36	2	.4186490	.00812749	.00574700	.3456264	.4916716	.41290	.42440
Total	72	.4529640	.14014672	.01651645	.4200311	.4858969	.22967	.73753

Cake types: (All the cakes are baked in conventional oven) 1: Control cake, 2: 0.3% guar gum containing cake, 3: 0.3% xanthan containing cake, 4: 1% guar gum containing cake, 5: 1% xanthan gum containing cake, 6: Gum blend containing cake, 7: Control cake stored for 24 h, 8: Cake containing 0.3% guar gum stored for 24 h, 9: 0.3% xanthan containing cake stored for 24 h, 10: 1% guar gum containing cake stored for 24 h, 11: 1% xanthan gum containing cake stored for 24 h, 12: Gum blend containing cake stored for 24 h, 13: Control cake stored for 48 h, 14: Cake containing 0.3% guar gum stored for 48 h, 15: 0.3% xanthan containing cake stored for 48 h, 16: 1% guar gum containing cake stored for 48 h, 17: 1% xanthan gum containing cake stored for 48 h, 18: Gum blend containing cake stored for 48 h, 19: Control cake stored for 72 h, 20: Cake containing 0.3% guar gum stored for 72 h, 21: 0.3% xanthan containing cake stored for 72 h, 22: 1% guar gum containing cake stored for 72 h, 23: 1% xanthan gum containing stored for 72 h, 24: Gum blend containing cake stored for 72 h, 25: Control cake stored for 96 h, 26: Cake containing 0.3% guar gum stored for 96 h, 27: 0.3% xanthan containing cake stored for 96 h, 28: 1% guar gum containing cake stored for 96 h, 29: 1% xanthan gum containing cake stored for 96 h, 30: Gum blend containing cake stored for 96 h, 31: Control cake stored for 120 h, 32: 0.3% guar gum containing cake stored for 120 h, 33: 0.3% xanthan containing cake stored for 120 h, 34: 1% guar gum containing cake stored for 120 h, 35: 1% xanthan gum containing cake stored for 120 h, 36: Gum blend containing cake stored for 120 h.

ANOVA

hardness

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.345	35	.038	28.134	.000
Within Groups	.049	36	.001		
Total	1.395	71			

hardness

Duncan[a]

caketype	N	Subset for alpha = .05														
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
6	2	.2412690														
5	2	.2555065	.2555065													
11	2	.2857050	.2857050	.2857050												
17	2	.2919210	.2919210	.2919210												
12	2	.2973825	.2973825	.2973825	.2973825											
2	2	.3004230	.3004230	.3004230	.3004230	.3004230										
23	2	.3037000	.3037000	.3037000	.3037000	.3037000	.3037000									
3	2		.3305740	.3305740	.3305740	.3305740	.3305740	.3305740								
9	2		.3315940	.3315940	.3315940	.3315940	.3315940	.3315940								
1	2			.3565535	.3565535	.3565535	.3565535	.3565535	.3565535							
18	2			.3682815	.3682815	.3682815	.3682815	.3682815	.3682815							
15	2			.3708755	.3708755	.3708755	.3708755	.3708755	.3708755							
7	2				.3813380	.3813380	.3813380	.3813380	.3813380	.3813380						
29	2					.3871220	.3871220	.3871220	.3871220	.3871220	.3871220					
24	2						.3900875	.3900875	.3900875	.3900875	.3900875					
13	2							.4079345	.4079345	.4079345	.4079345					
30	2							.4142055	.4142055	.4142055	.4142055					
36	2							.4186490	.4186490	.4186490	.4186490					
4	2								.4234710	.4234710	.4234710					
8	2								.4339055	.4339055	.4339055	.4339055				
19	2								.4377480	.4377480	.4377480	.4377480				
21	2									.4650810	.4650810	.4650810				
35	2									.4651690	.4651690	.4651690				
14	2										.4715520	.4715520				
25	2											.5174415	.5174415			
10	2												.5537285	.5537285		
27	2												.5549270	.5549270		
33	2												.5748135	.5748135	.5748135	
20	2												.5821335	.5821335	.5821335	
16	2													.6213460	.6213460	.6213460
26	2														.6505100	.6505100
22	2															.6639360
32	2															.6779175
28	2															.6896940
31	2															.6922235
34	2															.6979845
Sig.		.152	.084	.057	.059	.051	.052	.051	.072	.062	.061	.053	.126	.110	.068	.079

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.29 ANOVA and Duncan Single Range Test Table for hardness of cakes during storage formulated with different gums and gum concentrations baked in MW-IR combination and conventional oven

Descriptives

hardness120h

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	.7562426	.02034713	.01438759	.5734309	.9390543	.74186	.77063
2	2	.7348550	.01460527	.01032748	.6036318	.8660781	.72453	.74518
3	2	.7043981	.05572815	.03940576	.2037005	1.2050957	.66499	.74380
4	2	.8358664	.03803759	.02689664	.4941122	1.1776206	.80897	.86276
5	2	.6516112	.02330617	.01647995	.4422136	.8610088	.63513	.66809
6	2	.5893353	.04890185	.03457883	.1499696	1.0287010	.55476	.62391
7	2	.6922232	.06045270	.04274652	.1490772	1.2353692	.64948	.73497
8	2	.6779175	.03090118	.02185044	.4002814	.9555536	.65607	.69977
9	2	.5748132	.06514213	.04606244	-.0104656	1.1600920	.52875	.62088
10	2	.6979848	.05592560	.03954537	.1955132	1.2004564	.65844	.73753
11	2	.4651690	.04835822	.03419443	.0306876	.8996504	.43097	.49936
12	2	.4186489	.00812730	.00574687	.3456280	.4916698	.41290	.42440
Total	24	.6499221	.12127204	.02475455	.5987134	.7011308	.41290	.86276

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 0.3% guar gum containing cake baked in MW-IR combination oven, 3: 0.3% xanthan containing cake baked in MW-IR combination oven, 4: 1% guar gum containing cake baked in MW-IR combination oven, 6: 1% xanthan gum containing cake baked in MW-IR combination oven, 6: Gum blend containing cake baked in MW-IR combination oven, 7: Control cake baked in conventional oven, 8: 0.3% guar gum containing cake baked in conventional oven, 9: 0.3% xanthan containing cake baked in conventional oven, 10: 1% guar gum containing cake baked in conventional oven, 11: 1% xanthan gum containing cake baked conventional oven, 12: Gum blend containing cake baked in conventional oven.

ANOVA

hardness120h

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.316	11	.029	15.310	.000
Within Groups	.022	12	.002		
Total	.338	23			

Table A.29 Continued

hardness120h

Duncan[a]

caketype	N	Subset for alpha = .05				
		1	2	3	4	5
12	2	.4186489				
11	2	.4651690				
9	2		.5748132			
6	2		.5893353	.5893353		
5	2		.6516112	.6516112	.6516112	
8	2			.6779175	.6779175	
7	2				.6922232	
10	2				.6979848	
3	2				.7043981	
2	2				.7348550	
1	2				.7562426	.7562426
4	2					.8358664
Sig.		.304	.117	.075	.051	.091

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.30 ANOVA and Duncan Single Range Test Table for retrogradation enthalpy of cakes during storage formulated with different gums and gum concentrations, baked in MW-IR combination oven

Descriptives

retroent

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	4	.1360250	.01672391	.00836196	.1094135	.1626365	.11510	.15310
2	4	.1287500	.02054986	.01027493	.0960506	.1614494	.10760	.15490
3	4	.1492000	.00705219	.00352609	.1379784	.1604216	.14180	.15600
4	4	.2069500	.02683809	.01341905	.1642446	.2496554	.18390	.24060
5	4	.1608750	.01772294	.00886147	.1326739	.1890761	.14440	.17790
6	4	.0826550	.01135700	.00567850	.0645835	.1007265	.07011	.09662
7	4	.3012750	.01585820	.00792910	.2760411	.3265089	.28910	.32460
8	4	.2726500	.03387511	.01693756	.2187471	.3265529	.23930	.31980
9	4	.2351250	.02228742	.01114371	.1996607	.2705893	.21440	.26080
10	4	.3485250	.03773225	.01886612	.2884846	.4085654	.31210	.38320
11	4	.2491500	.05390767	.02695383	.1633709	.3349291	.18910	.31890
12	4	.2255750	.02236223	.01118111	.1899917	.2611583	.20180	.24520
Total	48	.2080629	.07973209	.01150834	.1849111	.2312147	.07011	.38320

Cake types: (All the cakes are baked in MW-IR combination oven) 1: Control cake stored for 24 h, 2: 0.3% guar gum containing cake stored for 24 h, 3: 0.3% xanthan containing cake stored for 24 h, 4: 1% guar gum containing cake stored for 24 h, 5: 1% xanthan gum containing cake stored for 24 h, 6: Gum blend containing cake stored for 24 h, 7: Control cake stored for 120 h, 8: Cake containing 0.3% guar gum stored for 120 h, 9: 0.3% xanthan containing cake stored for 120 h, 10: 1% guar gum containing cake stored for 120 h, 11: 1% xanthan gum containing cake stored for 120 h, 12: Gum blend containing cake stored for 120 h.

ANOVA

retroent

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.273	11	.025	34.450	.000
Within Groups	.026	36	.001		
Total	.299	47			

retroent

Duncan[a]

caketype	N	Subset for alpha = .05						
		1	2	3	4	5	6	7
6	4	.0826550						
2	4		.1287500					
1	4		.1360250					
3	4		.1492000					
5	4		.1608750					
4	4			.2069500				
12	4			.2255750	.2255750			
9	4			.2351250	.2351250	.2351250		
11	4				.2491500	.2491500		
8	4					.2726500	.2726500	
7	4						.3012750	
10	4							.3485250
Sig.		1.000	.130	.169	.249	.069	.140	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.31 ANOVA and Duncan Single Range Test Table for retrogradation enthalpy of cakes during storage formulated with different gums and gum concentrations, baked in conventional oven

Descriptives

retroent

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	4	.2169250	.03047178	.01523589	.1684376	.2654124	.17520	.24790
2	4	.1221000	.01649990	.00824995	.0958450	.1483550	.10350	.13910
3	4	.1029075	.01092484	.00546242	.0855236	.1202914	.08950	.11250
4	4	.1431750	.01599591	.00799796	.1177219	.1686281	.12230	.16120
5	4	.1191500	.04102597	.02051298	.0538685	.1844315	.07840	.17620
6	4	.1025200	.03000949	.01500475	.0547682	.1502718	.06148	.13220
7	4	.3666250	.01851709	.00925854	.3371602	.3960898	.35040	.39270
8	4	.3255000	.03593782	.01796891	.2683149	.3826851	.28650	.36800
9	4	.3385250	.03247321	.01623660	.2868529	.3901971	.30620	.37230
10	4	.3655250	.05348192	.02674096	.2804233	.4506267	.28900	.41100
11	4	.3431250	.03261752	.01630876	.2912232	.3950268	.29990	.37440
12	4	.3040000	.01404066	.00702033	.2816582	.3263418	.28460	.31810
Total	48	.2375065	.11215462	.01618813	.2049402	.2700728	.06148	.41100

Cake types: (All the cakes are baked in conventional oven) 1: Control cake stored for 24 h, 2: 0.3% guar gum containing cake stored for 24 h, 3: 0.3% xanthan containing cake stored for 24 h, 4: 1% guar gum containing cake stored for 24 h, 5: 1% xanthan gum containing cake stored for 24 h, 6: Gum blend containing cake stored for 24 h, 7: Control cake stored for 120 h, 8: Cake containing 0.3% guar gum stored for 120 h, 9: 0.3% xanthan containing cake stored for 120 h, 10: 1% guar gum containing cake stored for 120 h, 11: 1% xanthan gum containing cake stored for 120 h, 12: Gum blend containing cake stored for 120 h.

ANOVA

retroent

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.558	11	.051	55.519	.000
Within Groups	.033	36	.001		
Total	.591	47			

Table A.31 Continued

retroent

Duncan[a]

caketype	N	Subset for alpha = .05			
		1	2	3	4
6	4	.1025200			
3	4	.1029075			
5	4	.1191500			
2	4	.1221000			
4	4	.1431750			
1	4		.2169250		
12	4			.3040000	
8	4			.3255000	.3255000
9	4			.3385250	.3385250
11	4			.3431250	.3431250
10	4				.3655250
7	4				.3666250
Sig.		.097	1.000	.102	.093

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 4.000.

Table A.32 ANOVA and Duncan Single Range Test Table for peak viscosity of cakes during storage formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

peakviscosity

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	104.0000	.00000000	.00000000	104.0000000	104.0000000	104.0000	104.0000
2	2	215.0000	21.21320344	15.00000	24.4069290	405.5930710	200.0000	230.0000
3	2	190.0000	14.14213562	10.00000	62.9379526	317.0620474	180.0000	200.0000
4	2	163.0000	7.07106781	5.000000	99.4689763	226.5310237	158.0000	168.0000
5	2	238.0000	4.24264069	3.000000	199.8813858	276.1186142	235.0000	241.0000
6	2	209.0000	1.41421356	1.000000	196.2937953	221.7062047	208.0000	210.0000
7	2	119.5000	4.94974747	3.500000	75.0282834	163.9717166	116.0000	123.0000
8	2	212.0000	.00000000	.00000000	212.0000000	212.0000000	212.0000	212.0000
9	2	233.5000	13.43502884	9.500000	112.7910550	354.2089450	224.0000	243.0000
10	2	152.5000	2.12132034	1.500000	133.4406929	171.5593071	151.0000	154.0000
11	2	275.5000	9.19238816	6.500000	192.9096692	358.0903308	269.0000	282.0000
12	2	245.0000	.00000000	.00000000	245.0000000	245.0000000	245.0000	245.0000
Total	24	196.4167	51.51269718	10.51499	174.6647623	218.1685710	104.0000	282.0000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 1% xanthan gum containing cake baked in MW-IR combination oven, 3: Gum blend containing cake baked in MW-IR combination oven, 4: Control cake baked in MW-IR combination oven and stored for 120 h, 5: 1% xanthan gum containing cake baked in MW-IR combination oven and stored for 120 h, 6: Gum blend containing cake baked in MW-IR combination oven and stored for 120 h, 7: Control cake baked in conventional oven, 8: 1% xanthan gum containing cake baked in conventional oven, 9: Gum blend containing cake baked in conventional oven, 10: Control cake baked in conventional oven and stored for 120 h, 11: 1% xanthan gum containing cake baked in conventional oven and stored for 120 h, 12: Gum blend containing cake baked in conventional oven and stored for 120 h.

ANOVA

peakviscosity

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	60017.833	11	5456.167	64.570	.000
Within Groups	1014.000	12	84.500		
Total	61031.833	23			

peakviscosity

Duncan[a]

caketype	N	Subset for alpha = .05						
		1	2	3	4	5	6	7
1	2	104.0000						
7	2	119.5000						
10	2		152.5000					
4	2		163.0000					
3	2			190.0000				
6	2			209.0000	209.0000			
8	2				212.0000			
2	2				215.0000	215.0000		
9	2					233.5000	233.5000	
5	2						238.0000	
12	2						245.0000	
11	2							275.5000
Sig.		.118	.276	.061	.547	.067	.257	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

Table A.33 ANOVA and Duncan Single Range Test Table for setback viscosity of cakes during storage formulated with different gums and gum concentrations baked in MW-IR combination oven and conventional oven

Descriptives

setback

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	2	82.00000	.00000000	.00000000	82.0000000	82.0000000	82.00000	82.00000
2	2	117.5000	.70710678	.50000000	111.1468976	123.8531024	117.0000	118.0000
3	2	111.0000	7.07106781	5.000000	47.4689763	174.5310237	106.0000	116.0000
4	2	103.5000	.70710678	.50000000	97.1468976	109.8531024	103.0000	104.0000
5	2	133.0000	2.82842712	2.000000	107.5875905	158.4124095	131.0000	135.0000
6	2	121.0000	2.82842712	2.000000	95.5875905	146.4124095	119.0000	123.0000
7	2	92.50000	3.53553391	2.500000	60.7344882	124.2655118	90.00000	95.00000
8	2	116.0000	.00000000	.00000000	116.0000000	116.0000000	116.0000	116.0000
9	2	127.0000	1.41421356	1.000000	114.2937953	139.7062047	126.0000	128.0000
10	2	107.5000	4.94974747	3.500000	63.0282834	151.9717166	104.0000	111.0000
11	2	130.0000	4.24264069	3.000000	91.8813858	168.1186142	127.0000	133.0000
12	2	141.0000	.00000000	.00000000	141.0000000	141.0000000	141.0000	141.0000
Total	24	115.1667	16.87206765	3.443996	108.0422173	122.2911160	82.00000	141.0000

Cake types: 1: Control cake baked in MW-IR combination oven, 2: 1% xanthan gum containing cake baked in MW-IR combination oven, 3: Gum blend containing cake baked in MW-IR combination oven, 4: Control cake baked in MW-IR combination oven and stored for 120 h, 5: 1% xanthan gum containing cake baked in MW-IR combination oven and stored for 120 h, 6: Gum blend containing cake baked in MW-IR combination oven and stored for 120 h, 7: Control cake baked in conventional oven, 8: 1% xanthan gum containing cake baked in conventional oven, 9: Gum blend containing cake baked in conventional oven, 10: Control cake baked in conventional oven and stored for 120 h, 11: 1% xanthan gum containing cake baked in conventional oven and stored for 120 h, 12: Gum blend containing cake baked in conventional oven and stored for 120 h.

Table A.33 Continued

ANOVA

setback

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	6423.333	11	583.939	56.510	.000
Within Groups	124.000	12	10.333		
Total	6547.333	23			

setback

Duncan[a]

		Subset for alpha = .05								
caketype	N	1	2	3	4	5	6	7	8	9
1	2	82.00000								
7	2		92.50000							
4	2			103.5000						
10	2			107.5000	107.5000					
3	2				111.0000	111.0000				
8	2					116.0000	116.0000			
2	2					117.5000	117.5000			
6	2						121.0000	121.0000		
9	2							127.0000	127.0000	
11	2								130.0000	
5	2								133.0000	
12	2									141.0000
Sig.		1.000	1.000	.237	.298	.078	.164	.087	.100	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 2.000.

APPENDIX B

DSC THERMOGRAPHS

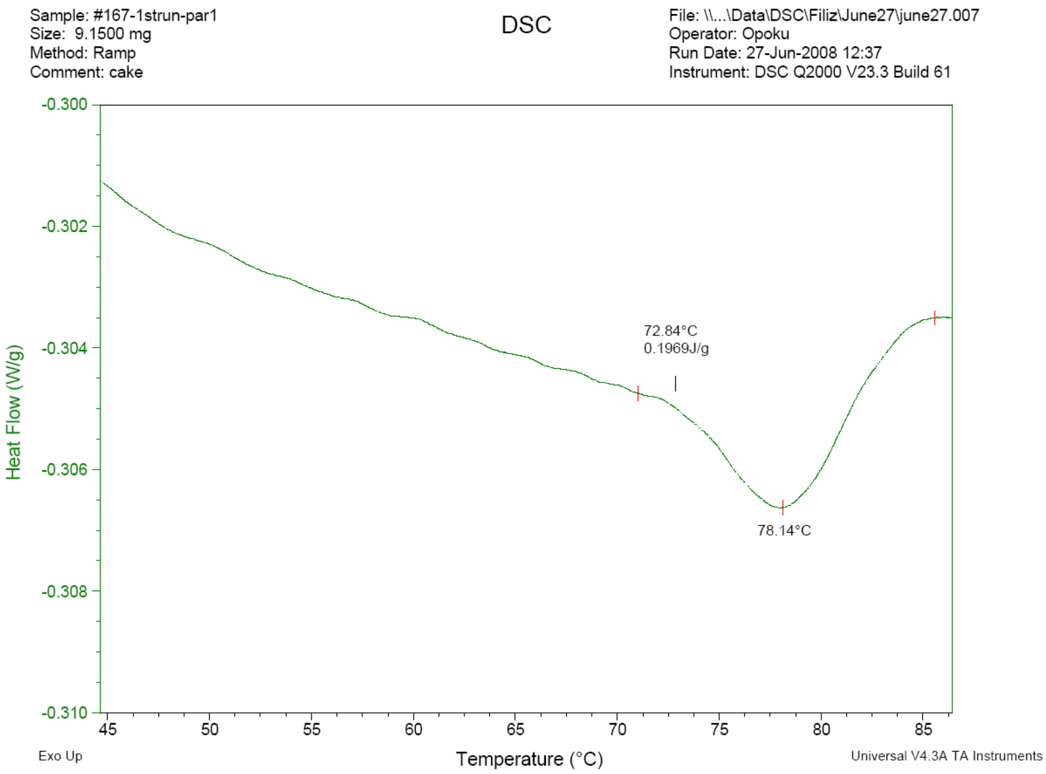

Figure B.1 DSC thermograph of the control cake baked in MW-IR combination oven

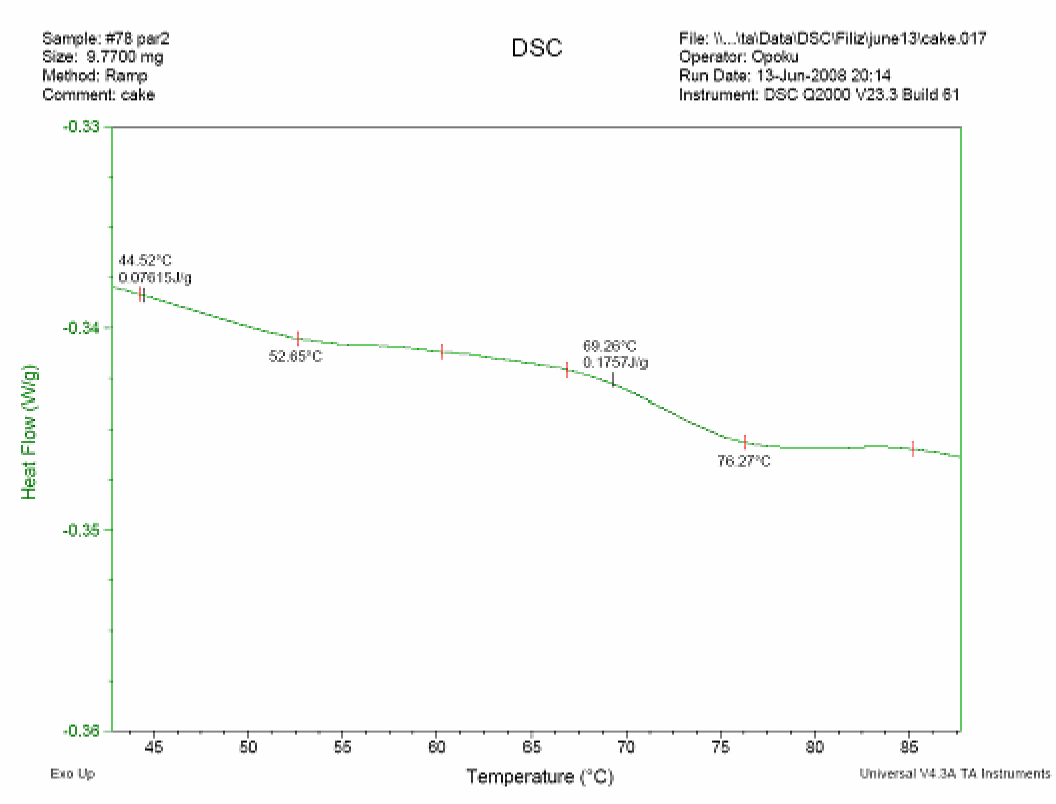

Figure B.2 DSC thermograph of the control cake baked in conventional oven and stored for 120 h

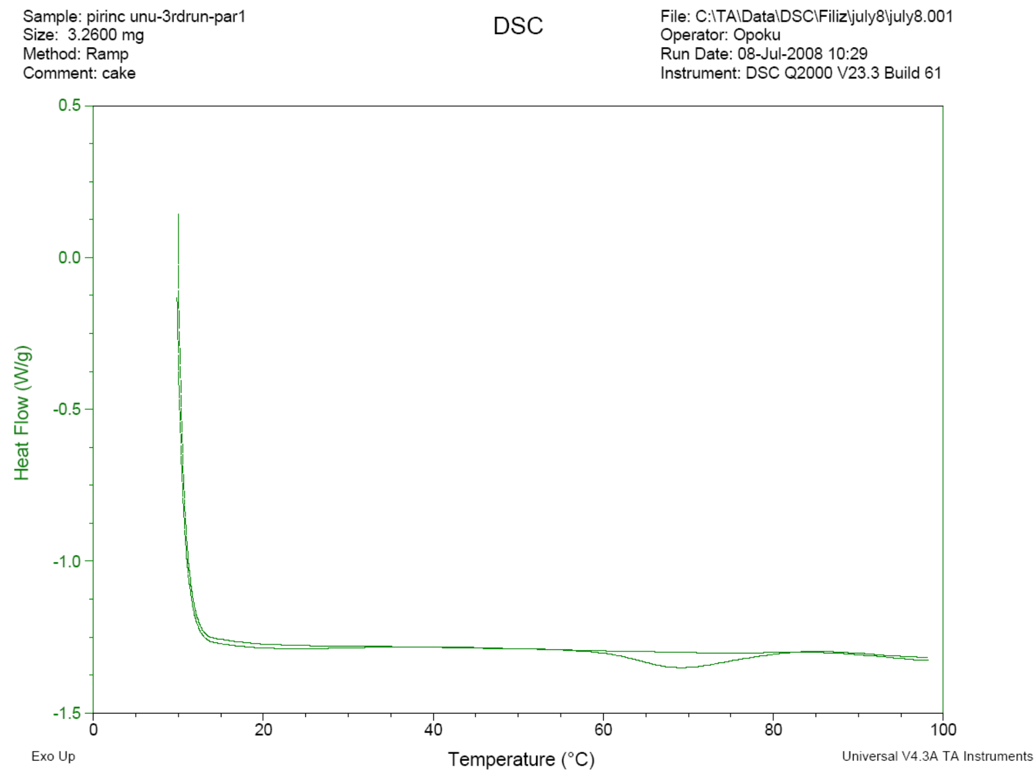

Figure B.3 DSC thermograph of rice flour