EFFECTS OF DIFFERENT FLOUR, GUM AND PROTEIN TYPES ON QUALITY OF GLUTEN-FREE CAKES

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ABSTRACT

EFFECTS OF DIFFERENT FLOUR, GUM AND PROTEIN TYPES ON QUALITY OF GLUTEN-FREE CAKES

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The main objective of this study was to investigate the influence of flour type, concentration, gum/protein type on rheological, physical and morphological behavior of gluten free cake batter, and to study impact of them on cake quality.

In the first part of the study, the effects of partial replacement of rice flour with buckwheat flour, or carob bean flour at different concentrations (10%, 20%, 30%), and addition of different types of gums (xanthan gum, guar gum), or proteins (soy protein and whey protein) on rheological properties, and morphological characteristics of gluten free cake batters were analyzed. In the second part of the study, quality of cakes (weight loss, porosity, specific volume, hardness, color and image analysis) were investigated.

Power law model was found to be the most suitable model to express flow behavior of cake batters. Flour type and concentration were the main factors that affected apparent viscosity. Gum containing batters exhibited higher apparent viscosities. Low specific gravity and more homogenous distribution of gas bubbles were observed in whey protein added batter samples.

Increasing flour concentration decreased moisture loss, porosity and specific volume of cakes. On the other hand, it increased hardness value. Whey protein added cakes had the highest quality (high porosity, high specific volume, and low hardness). On the other hand, cakes containing guar gum had the most unacceptable quality. Higher quality could be achieved when cakes were formulated with buckwheat flour rather than carob bean flour. As a result, cakes prepared with 10% buckwheat flour and whey protein can be recommended to be used in gluten free cakes.

Key Words: baking, buckwheat flour, carob bean flour, rheology, gluten free cake

ÖZ

DEĞİŞİK UN, ZAMK VE PROTEİN ÇEŞİTLERİNİN GLUTENSİZ KEKLERİN KALİTELERİNE OLAN ETKİSİ

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Bu çalışmanın temel amacı un çeşidinin, konsantrasyonunun ve zamk/ protein çeşidinin glutensiz kek hamurlarının reolojik, fiziksel ve morfolojik özelliklerin üzerine olan etkisinin araştırılması ve bu değişkenlerin kek kalitesi üzerine olan etkilerinin incelenmesidir.

Çalışmanın ilk kısmında, pirinç unu yerine kısmi olarak farklı konstantrasyonlarda (%10, %20, %30) karabuğday unu ya da keçiboynuzu unu ve farklı zamk (ksantan zamkı ve guar zamkı), ya da protein (soya ve peynir altı suyu tozu) çeşitlerinin glutensiz kek hamurlanının reolojik ve morfolojik özellikleri üzerine olan etkileri analiz edilmiştir. Çalışmanın ikinci kısmında ise, keklerin kaliteleri (ağırlık kaybı, porozite, özgül hacim, sertlik, renk ve görüntü analizleri) incelenmiştir.

Kek hamurlarının akış davranışını açıklamak için en uygun model Power yasası olmuştur. Un çeşidi ve konsantrasyonu görünür vizkoziteyi etkileyen en temel faktörlerdir. Zamk içeren hamurlar yüksek görünür vizkozite değerleri göstermişlerdir. Peynir altı suyu içeren kek hamurlarında düşük özgül hacim ve gaz kabarcıklarının homojen dağılımları gözlemlenmiştir.

Un konsantrasyonunun artması keklerin ağırlık kaybını, porozite ve özgül hacim değerlerini azaltmıştır. Diğer taraftan sertlik değerini arttırmıştır. Peynir altı suyu eklenen kekler en iyi kaliteye (yüksek porozite, yüksek özgül hacim, ve düşük sertlik) sahip olmuşlardır. Öte yandan, guar zamkı içeren kekler en kabul edilemez kalitede olanlardır. Karabuğday unu eklenen keklerde, keçiboynuzu unu içerenlere göre daha yüksek kalite elde edilmiştir. Sonuç olarak, %10 karabuğday unu ile hazırlanan ve peynir altı suyu proteini katılan kekler glutensiz keklerde kullanılmak üzere önerilebilir.

Anahtar Kelimeler: pişirme, karabuğday unu, keçiboynuzu unu, reoloji, glutensiz kek

To my lovely mom..

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INTRODUCTION

1.1 Celiac Disease

Celiac disease is described as immune mediated disorder of intestinal mucosa that is triggered by protein; gluten (Mendoza, 2005). Actually, celiac patients respond to dietary proteins; namely prolamins. Although all grains even rice include prolamins, some certain prolamins present in barley (horedin), rye (secalin), and wheat (gliadin) are the ones that stimulate and initiate immunological reactions (Pietzak, 2012).

The frequency of celiac disease among adults is approximated to be 0.5%- 1% of the population (Pietzak, 2012). Furthermore, according to researches including US and Europe, frequency of disease among children who are 2.5 - 15 years old is 0.13% to 0.3% (Anonymous, 2005). Indeed, celiac disease can appear at any time of life span. However, adults generally experience this disease after 50 year old. Furthermore, according to studies, between celiac patients; male to female ratio is almost 1:3 (Feighery, 1999), which means that males are less affected than females. However, people who have genetic susceptibility to type 1 diabetes, rheumatoid arthritis, autoimmune thyroid disease and patients with

Turner syndrome, Williams syndrome and Down syndrome are under the risk of being celiac patient (Pietzak, 2012). The prevalence of celiac disease in Turkey was approximated as 1.3%, which was higher than general estimation (Elsurer et al., 2005).

The best known reason of chronic malabsorption is celiac disease, since it causes damage to absorptive surface area of small intestine. This leads to imbalanced absorption of nutrients briefly folic acid, B12 vitamin, iron and fat soluble vitamins, and reduction in digestive enzymes. Consequently, all these result in bloating, abdominal pain and weight loss (Rubio-Tapia, Hill, Kelly, Calderwood, & Murray, 2013)**.** Extraintestinal symptoms of celiac disease can be observed in many organs such as dental enamel defects, muscle pain, and osteoporosis. In addition to these, depression, headache, anxiety are the common neurologic symptoms of celiac disease (Pietzak, 2012).

Bakery products like biscuits, pasta, bread, and cake are well known gluten sources. However, the only cure of celiac disease is the removal of gluten from diet. Contrary to popular belief, adaptation to gluten free diet is not easy. In some cases, it can result in isolation of celiac patients from society. Therefore, this is the reason why gluten free goods should be produced (Hamer, 2005). Moreover, celiac patients have to obey a well-balanced and healthy diet (Mendoza, 2005).

1.2 Gluten

A large quantity of proteins present in seed have role in either structural or metabolic function. Some of these proteins are responsible from storage of high amount amino acids and rest is in charge of seedling growth. Furthermore, these storage proteins have role in not only total protein content but also quality of end product (Shewry, Napier, & Tatham, 1995). In wheat, storage protein composes of 80% of all protein content in grain. Since gliadins and glutenin have high levels of glutamine and proline amino acids, they are called as storage proteins (Veraverbeke & Delcour, 2010). Although these proteins are both insoluble in water at pH 7 and dilute salt solutions, they can be differentiated according to their ethanol solubility. Gliadins are soluble in ethanol, but the other storage protein which is glutenin is insoluble in ethanol solution. Furthermore, water soluble proteins in grain are classified as albumins and salt soluble proteins are termed as globulins (Payne, Holt, Lawrence, & Law, 1982). Gliadin has low molecular weight and do not include any disulfide bond in its structure. On the other hand, glutenins have higher molecular weight and a heterogeneous structure composed of 19 different subunits which are connected each other by disulfide bonding. Furthermore, glutenin subunits are divided into two group; low molecular weight and high molecular weight (Payne, 1987). Gliadin, is divided into three subgroups α-, γ- , ω-. Cysteine residues has an importance for both gliadin and glutenin since they make disulfide bonds with either between different polypeptides (inter chain disulfide bond) or the same polypeptides (intra-chain disulfide bond) (Veraverbeke & Delcour, 2010). These disulfide bonds formed by sulphydryl groups have important effect on stabilizing ability and functional property of dough (Shewry & Tatham, 1997). Glutenin gives elasticity to dough due to mostly hydrogen bonds, non-covalent interaction (van der Walls', hydrophobic and electrostatic) and disulfide bonds within and between glutenin proteins. Moreover, gliadin behaves as a plasticizer that moderate bond strength which glutenin forms. Therefore, proportion between polymeric glutenin and monomeric gliadin molecules regulate balance between dough elasticity and viscosity (Veraverbeke & Delcour, 2010; Shewry & Tatham, 1997). Therefore, storage proteins clearly affect the rheological properties of dough. These are affected also by many factors strength of bonds between proteins, structure of the polymeric components (branched or linear), quantity of bonds (both covalent and noncovalent), and distribution ratio of polymers (Shewry & Tatham, 1997).

1.3 Gluten Free Flour Types

People suffering from celiac disease have to exclude any food containing gluten from their diet. Rice flour is generally regarded as main ingredients of gluten free product formulations (Sanchez, Osella, & De La Torre, 2002; Torbica, Hadnadev, & Dapcevic, 2010; Turabi, Sumnu, & Sahin, 2008). Moreover, chestnut flour (Demirkesen, Mert, Sumnu, & Sahin, 2010b), soy flour (Menon, Dutta Majumdar, & Ravi, 2014), sorghum and quinoa (Hager et al., 2012) are alternatives of gluten free flours. However, it is necessary to replace wheat flour with other flour that contain high amount of minerals, vitamins, fiber since celiac patients have some problems to get well balanced diet. Therefore, lupin, buckwheat (Levent & Bilgiçli, 2011), chickpea, bean, lentil, pea (Gularte, Gómez, & Rosell, 2012), carob bean flour (Tsatsaragkou, Gounaropoulos, & Mandala, 2014) are regarded as good alternatives due to their high nutritional value. In this research, buckwheat and carob bean flour were selected nutritional effects and rice flour were preferred its bland texture.

1.3.1 Rice Flour

Rice flour is one of the non-wheat cereal that is commonly preferred in gluten free formulations for celiac patients. In addition to having high level of readily digested carbohydrates, low amount of fat, sodium, fiber and protein makes rice flour be the most favorite gluten free flour. Hypo-allergic feature, colorless appearance and bland taste are other reasons of preference (Sanchez, Osella, & Torre, 2002; Ji, Zhu, Qian, & Zhou, 2007; Torbica, Hadnadev, & Hadnadev, 2012).

However, production of bakery products with rice flour brings some restrictions. Although the storage proteins which are glutelins and prolamins (40-50%) provide extension, viscosity and elastic ability to wheat dough, and increase gas retention capacity, rice has low amount of prolamin (2.5-3.5%) and cannot maintain the gas generated during kneading, baking or fermentation process. This problem results in poor quality parameters such as firm texture, and low specific volume (Singh & Rosell, 2004). To overcome these circumstances and to give batter to viscoelastic property, which gluten provides; some polymers are commonly utilized such as gums; xanthan, guar, hydroxyl propyl methyl cellulose, pectin; (Torbica et al., 2012), different starches; corn, cassava (Sanchez et al., 2002), potato starch (Anton & Artfield, 2016) and proteins; whey protein (Sarabhai & Prabhasankar, 2015).

1.3.2 Buckwheat Flour

Pseudo-cereal refers to a plant which does not belong to grass family but producing more starchy grain, seed and fruit. Buckwheat, amaranth and quinoa are the best known pseudo cereals. Cereals have larger seeds than pseudo cereals. In addition, pseudo-cereals can be grown in hard conditions such as poor soils where cereals can't. One cereal grain has an embryo, high amount of endosperm and a seed coat. Moreover, they are known as monocotyledonous plant. On the other hand, pseudo cereals are one type of the dicotyledonous plants. In addition to that it has a perisperm instead endosperm. Unfortunately; up to now, pseudocereals have not gained enough importance in a world wide. However, they should be more commonly used human diet especially those that have tendency to alergetic reaction to traditional cereals (Wrigley, Harold, Koushik, & Jon, 2016).

Buckwheat is one of the pseudo-cereals which has already known to have many health benefits. For example; it is very rich in terms of polyphenols and flavonoids (Table1.1) (Torbica et al., 2012). Rutin and its derivatives have a significant influence on protection of edema, improvement of vascular fragility, transmittance, and antihemorrhagic attribution. One of the types of quercetin present in buckwheat has an inhibitory effect on lipoprotein oxidation (Sakac, Torbica, Sedej, & Hadnadev, 2011). Because digestions of buckwheat carbohydrate monomers are slower; it is beneficial to gain glucose tolerance (Table 3.1). In addition, it has an effect on also reducing cholesterol due to high amount of mineral content. Buckwheat has very special amino acid sequence which makes it one of the most important plant origin types of protein sources (Mariotti, Pagani, & Lucisano, 2013). Globulins and albumins are main protein types present in buckwheat (Torbica et al., 2012). Furthermore, it is a good source of dietary fiber. For example in buckwheat seeds, ratio of non-polysaccharide fraction is almost 28%. This is very important for people especially celiac patients who do not include enough amount of dietary fiber in their diet. In additional to those, it is suitable for producing low glycemic index foods since almost 35% of overall starch content of buckwheat is from resistance starch (Mariotti et al., 2013).

Although buckwheat has many benefits, there are limited researches about it. A study conducted in 2014 mainly focused on the relationship between rheological properties and quality of gluten free bread prepared with chickpea, millet, rice, corn, quinoa, and buckwheat (Burešová, Kráčmar, Dvořáková, & Středa, 2014).

Another research was about sensorial and physicochemical characterization of buckwheat biscuit with guar gum, gum acacia, xanthan gum, and gum tragacanth. Biscuits prepared with buckwheat and xanthan gum had comparably similar quality with biscuit with wheat flour (Burešová et al., 2014).

Another study was related to antioxidant activity and stability level of buckwheat gluten free breads. It was found out that there was no significant reduction in nutritional values of the products. Moreover, it was concluded that antioxidant activity and stability were also strongly dependent on their formulation (Sakac et al., 2011).

The effect of hydroxypropyl methylcellulose (HMPC) and buckwheat flour on bread quality was analyzed in terms of specific volume, crumb texture, weight, height, and color (Mariotti et al., 2013). It were concluded that addition of buckwheat up to some extend improved leavening properties of dough which had a positive effect on bread quality. Addition of buckwheat increased viscosity of dough due to dietary fiber. Combination of HMPC and buckwheat reduced water loss of bread, and led to softer texture.

Table 1. 1 Buckwheat flour composition adapted from Giménez-Bastida, Piskuła, & Zieliński, 2015

Category	Compounds/ distribution	Concentration
Phenolic Compounds	Rutin/ groats	80.94mg/g in TB and 0.20 mg/g in CB
	Quercetin/ groats	0.001 mg/g DW
	Quercetin/hull	0.009-0.029 mg/g DW
Carbohydrate	Phytic acid/bran without hull	35-38 mg/g
Vitamins	Thiamine(B1)/ seeds	2.2- 3.3 µg/g
	Riboflavin (B2)/seeds	10.6 µg/g DW18
	Niacin(B3)/ seeds	18 µg/g
	Pantothenic acd (B5)/seed	11 µg/ g
	Vitamin C/seeds	50 µg/ kg DW

Table (1.1) continued

	Vitamin C/ sprouts	250 µg/ kg DW
Tripeptides	Glutatione/groats	1.1 µmol/g DW
Lipophilic LMWA	Tocopherols /groats	14.3-54.6 µg/g
	Carotenoids/seeds	2.1 µg/g DW
Lipophilic LMWA: phytosterols	β-sitosterol/dehulled groats	0.7 µg/g DW
	β- sitosterol/ buckwheat flour	0.86mg/g DW
	Campesterol/groats	0.09 mg/g
	Compesterol/buckwheat flour	0.11mg/DW

(LMWA) Low molecular weight antioxidants; (DW) dry weight; (TB) Tartary buckwheat; (CB) Common buckwheat

1.3.3 Carob Bean Flour

Carob tree which belongs to Leguminosea family is also known as Ceratonia siliqua L., Fabaceae. It is commonly cultivated in Mediterranean area. Carob fruit is composed of two different parts. The first one dark brown husk, and the second one is seeds. Although 80-90% of the fruit is husk (80-90%) and rest of it is seed (20-10%), 50-60% of the carob fruit is sugar mainly sucrose, fructose, and glucose. Because of this high sugar content, they have been used as a sweetener. In addition to sweetener ability of carob fruit, due to low price and similar flavor with chocolate and cacao, carob fruit has been used as replacer of chocolate in industry (Seczyk, Swieca, & Sziki- Gawlik, 2016). While protein portion of fruit changes from 1% to 5%, fat contributes very low amount of fruit (0.2% -0.8%). On the other hand, crude fiber amount is very high which varies between 9% -13% of the whole fruit. Moreover, it contains significant amount of minerals (1-6%) mainly calcium, potassium, magnesium, and phosphor. As can be seen from the Table 1.2; carob bean flour contains high amount of unsaturated fatty acids rather than saturated fatty acids. Furthermore, Table 1.3 shows carob bean flour has high amount of amino acids in varying concentrations. Nonetheless, wheat is lack of essential amino acids like lysine, since during milling operation; it loses lots of minerals and vitamins. Due to significant amount of dietary fiber, carob bean flour also shows cholesterol lowering ability (Salinas, Carbas, Brites, & Puppo, 2015).

In addition to the production of carob flour from fruit, endosperm of carob bean seeds is composed of galactomannan which is fairly useful for not only in food industry but also in paper, textile, pharmaceutical and petroleum industries. Galactomannan is a polysaccharide formed by combination of galactose and mannose units. Carob bean seeds are used in food industry as gum which is known as locust bean gum (E410), a thickening or stabilizing agent. (Karababa & Coşkuner, 2013).

Carob bean seeds contain a protein called caroubin that shows similar rheological properties with wheat gluten but their chemical compositions are different. Proteins with different sizes come together and polymerize to form caroubin, water insoluble protein found in carob bean embryo (Tsatsaragkou et al., 2012). This makes carob flour a favorite replacer of gluten for celiac patients.

Moreover, germ of carob flour contains high amount of phytochemicals which are polyphenols, gallotannins and proanthocyanidins. They prevent the excess amount of reactive oxygen species and free radical formation (Custodio et al., 2011).

Table 1. 2 Fat and sugar composition of carob bean flour, adopted from Ayaz et al., 2009

Fatty Acids	Amount of fatty acids (µg/g dry weight)
C16:0	257±4
C16:1n-7	4.6±0.2
C18:0	47.1±1.4
C18:1n-9	730±18
C18:1n-7	12.8±0.4
C18:2n-6	208±8
C18:3n-3	57.3±2.4
C20:0	7.6±1.3
C22:0	9.9±1.3
C22:1	20.5±3.4
Total fat	1030±40
%saturation	23.7
% unsaturation	76.3
MUSFA	768
PUSFA	265
Sugars(mg/g dry weight)	
Fructose	73.9±5.5
Glucose	53.4±2.8
Sucrose	309±5

MUSFA: monounsaturated fatty acid

PUSFA: polyunsaturated fatty acid

Table 1. 3 Protein composition of carob bean flour, adopted from Ayaz et al., 2009

Amino acids	Amount of amino acids (mg/g dry weight)
Aspartic	2.19±0.10
Threonine	1.00±0.05
Serine	1.06±0.05
Glutamic	2.47±0.11
Glycine	0.95±0.04
Alanine	1.19±0.04
Valine	1.21±0.07
Isoleucine	0.86±0.05
Leucine	1.41±0.08
Tyrosine	0.61±0.06
Phenylalanine	0.75±0.05
Histidine	0.56±0.02
Lysine	0.26±0.02
Arginine	0.32±0.01
Cysteine	0.41±0.01
Proline	1.05±0.05
Methionine	0.33±0.02
tryptophan	n.d

n.d: not detected

Tsatsaragkou et al., (2012) analyzed combination of rice and carob bean flour on porosity, and firmness of bread. Optimum ratios (carob bean flour/ water amount) were recorded as 10/110, 15/ 130 and 15/140. Porosity value was affected both by water and carob flour amount. It was stated that although increasing water content increased porosity, increasing carob flour amount decreased that value. Both increasing water and carob flour amount led to decreasing of firmness (Tsatsaragkou et al., 2012).

According to the study conducted by Seczyk et al., (2016) the effect of carob bean flour addition on quality of wheat pasta was evaluated. It was examined in terms of antioxidant capacity, phenolic content, sensory analysis and nutritional quality. It was concluded that addition of carob bean flour increased phenolic and antioxidant property of pasta which was relevant to the added carob flour amount. Although glycemic index showed on increasing trend with increasing substitution level, decreasing tendency in digestibility of studied nutrient was observed.

Minarro, Albanell, Aguilar, Guamis, & Capellas, (2012) investigated the effect of high protein containing flours (soya, pea isolate, and chickpea and carob germ flour) on quality of bread. It was reported that dough with carob germ flour had thicker structure than others. Bread with chickpea flour reached the highest specific volume but bread with carob had the lowest specific volume. Correspondingly with specific volume, the lowest texture was achieved in the presence of chickpea. Result of the scanning laser microscopy revealed that bread with carob germ flour got stiffer structure contrary to chickpea and soya formulations.

1.4 Gums, Proteins and Emulsifiers Used in Gluten Free Products

Producing a gluten free product has some difficulties due to the absence of gluten which has significant influence on cell formation, porosity, volume, crust and crumb characteristics. As expected, gluten free products generally have low quality parameters. Studies showed that products without gluten can maintain gas inside the structure in presence of gluten mimicing material. Hydrophilic biopolymers with high molecular weight are commonly named as hydrocolloids. One of these biopolymers is gum that has high water solubility and makes very viscous solution even at low concentrations. Furthermore, they improve cohesive forces between starch granules, stabilizers, and pre- gelatinized stretches and are widely used in food industry to mimic gluten behavior. Thus, hydrocolloids are used in gluten free products for thickening gelling, texture improvement purposes. (Naji-Tabasi & Mohebbi, 2015; Mohammadi, Sadeghnia, Azizi, Neyestani, & Mortazavian, 2014; Lopes et al., 2015). The most common hydrocolloids used in baking industry are xanthan gum, guar gum, locust bean gum, HPMC, pectin and carrageenan gum. These are the hydrocolloids most commonly used in food industry (Kaur, Shevkani, Singh, & Sharma, 2015).

1.4.1 Xanthan Gum

Xanthan gum is an anionic polysaccharide commercially produced by *Xanthomonas campestris* bacteria. It has strong ability to raise batter stability, and gas maintenance. Moreover, xanthan can increase water holding capacity. This may be explained by hydroxyl groups which increases the number of hydrogen bonds leading to more interaction with water. In addition to that, xanthan has pseudoplastic characteristics and shows synergistic effect with some polysaccharides like glucomannas and galactomannans. They can improve more gelation and viscoelastic ability (Mohammadi et al., 2014; Burešová, Masaříková, Hřivna, Kulhanová, & Bureš, 2016) . It can be hydrated in cold water and form a viscous solution showing shear thinning behavior. Xanthan gum solution is insensitive to temperature change which means that batter can keep highly viscous ability during baking (Naji-Tabasi & Mohebbi, 2014).

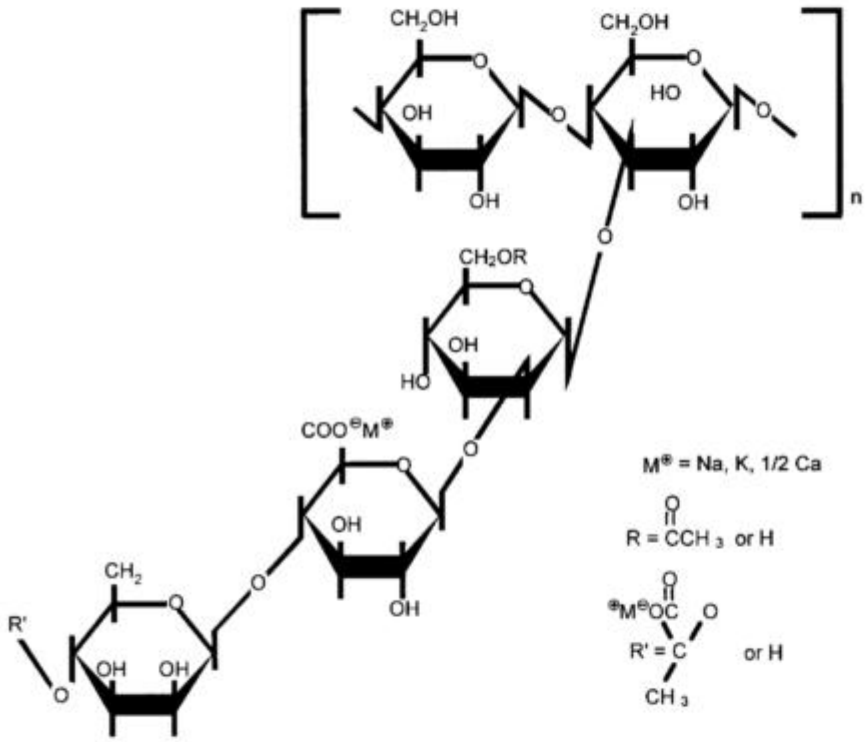

Figure 1. 1 Structure of xanthan gum (Monsanto, 2009).

Xanthan chemical composition can be represented as cellulose backbone, which includes 3 to 8 monosaccharaides branched or unbranched from (Figure1.1). Basically, it consists of D- glucuronic acid, D-mannose, and D-glucose. Glucose units links each other with β-1,4 glycosidic bond branching through carbon-3 atoms. The branches are formed by D-mannopyranose-(2,1)-β-D-glucuronic acid-(4,1)-β-D-mannopyranose. Furthermore, less than 40% terminal mannose groups have a pyruvic acid unit attached as a ketal to 4-6 positions (Ptaszek, Lukasiewicz, Achremowicz, & Grzesik, 2007).

1.4.2 Guar Gum

Guar gum is one of the naturally occurring, water soluble, non-ionic and nontoxic polysaccharide having very high molecular weight. It is the seeds of cluster bean (Cyamopsis tetragonolobus L.) which consists of many layers from inside to outside endosperm (34-40%), the germ (43-46%), and outer shell (16-18%). Although the germ part is composed of mainly protein, endosperm portion is predominantly galactomannan that is constituted by galactose and mannose units. Mannose to galactose ratio in guar gum is generally 2:1 (Sandhu, Simsek, & Manthey, 2015).

While the linear sequence of D-mannopyranosy is linked each other by β (1→4) bonds, D-galactopyranosyl is attached to each one by α (1→ 6) bonds. It is generally preferred as a thickening agent in drink and food industry because it can make very a viscous solution at low concentrations. The effect of guar gum on viscosity mainly depends on molecular weight of galactomannan. Guar gum has good dissolving or swelling ability in polar solvents due to strong hydrogen bonds. Even at lower than 1% concentration can increase viscosity. On the other hand, in nonpolar solvents it can make only weak hydrogen bond (Moser, Cornelio, & Nicoletti Telis, 2013).

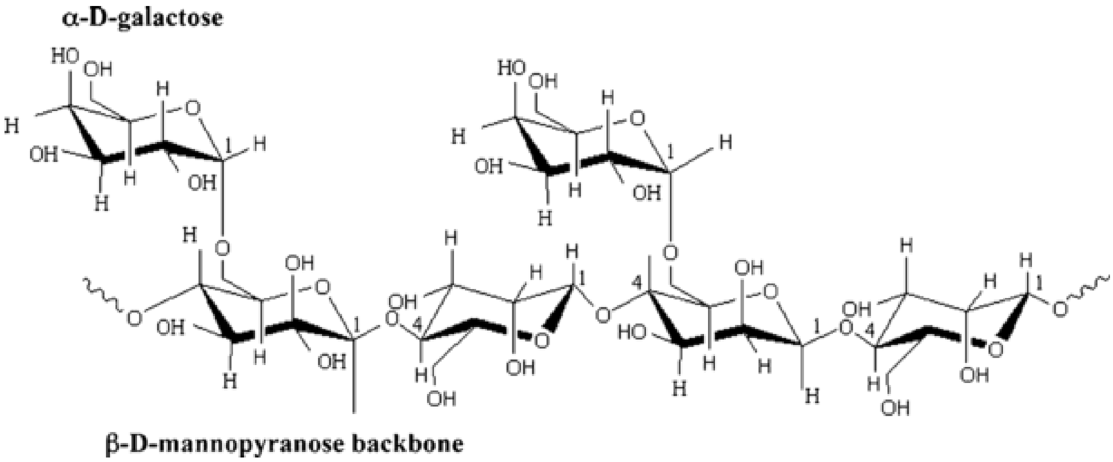

Figure 1. 2 Structure of guar gum (Mudgil, Barak, & Khatkar, 2014)

Guar gum in aqueous system generally shows pseudo-plastic behavior that means while shear rate increases, viscosity of the solution decreases. Guar gum is frequently preferred in food systems as a fiber source and a stabilizer since it affects behavior of water present in the system. In addition to that, it is offered:

- In gluten free bakery products to mimic gluten behavior and water retention,
- In yoghurt production as a texture improver viscosity controller,
- In ice cream to decrease the particle size of ice crystals, and
- In ketchup production due to consistency improver ability and texture modification (Mudgil, Barak, & Khathar, 2014).

1.4.3 Whey Protein

Whey protein is a valuable byproduct of cheese industry. It is frequently preferred as an ingredient in bakery industry because of its functional attributes and high nutritional value. It contains essential amino acids particularly lysine, leucine and methionine. Furthermore, whey protein is a good source of vitamins.

In addition to that whey protein improves color, flavor, and textural characteristics of the product (Silva, Marques, Freitas, & Madeira, 2016). Like other proteins, whey protein has amphiphilic structure which provides stabilizing ability in emulsion systems such as in water and oil interface. Therefore, whey protein has high solubility, good emulsifying ability, good foaming and gelling property. During preparation of dough in a mixer, mechanical shear stress is introduced to the system, which leads to formation of oil and water droplets. Due to their amphiphilic nature, whey proteins present in the aqueous part move toward to oil water interphase. It realigns itself according to the forming emulsion system, hydrophobic part towards oil phase and hydrophilic part through the water phase. Then, accumulation of protein at the interphase starts and they begin to combine each other to create a viscoelastic film that covers the oil droplets which makes emulsion stable (Lam & Nickerson, 2015). Whey proteins are α-lactalbumin, β- lactoglobulin , immunoglobulins, and bovine serum albumin. They correspond to 70% of overall content in whey and they are mainly responsible from foaming, gelation, emulsification and hydration properties (Panaras, Moatsou, Yanniotis, & Mandala, 2011). In many products, both polysaccharides and proteins are present together and it was proved that presence of polysaccharide enhances effectiveness of proteins (Panaras et al., 2011). Therefore, it can be suggested that adding any protein to formulations may solve problem related to gluten free products. Furthermore, commercial bakery products such as biscuit and bread contain low amount of protein roughly 7-8% and can be fortified with proteins, vitamins and minerals. Adding protein to baked product can be the solution of malnutrition (Indrani, Prabhasankar, Rajiv, & Rao, 2007).

The effect of replacement egg protein with whey protein on wheat flour cakes were studied by Jyotsna, Manohar, Indrani, & Rao, (2007). Cakes with whey protein had lower viscosity values than cakes with egg protein. Moreover, incorporation of whey protein to the batter increased the number of air cell in cake.

Whey protein addition at different ratios (5, 7.5, 10%) to gluten free cakes was examined in terms of rheological properties and quality of cake (Sarabhai & Prabhasankar, 2014). It was found out that cakes with higher amount of whey protein had higher hardness value. Furthermore, cake batter containing whey protein showed more solid like elastic behavior therefore it had higher storage modulus.

1.4.4 Soy Protein

One of the most important plant source protein is soy beans, which meets 70% of whole protein consumption. Especially in last decade, although cereals have been commonly used as energy supplement, they have failed to satisfy protein requirement particularly essential ones. On the other hand, soy proteins having high nutritional value has been regarded as an economical source of protein; especially lysine. Soy protein isolate refers to fairly purified form of soy protein, at least 90% protein concentration. Soy proteins assist health promotion by reducing risk of cancer and cardiovascular disease due to having large amounts of isoflavones. It is rich in minerals and vitamins, also. Furthermore, some researches has indicated that soy protein isolate enhanced with sulfur containing amino acid has the same biological value with animal protein such as casein (Majzoobi, Ghiasi, Habibi, Hedayati, & Farahnaky, 2014).

Addition to health benefits, soy and its derivatives have ability to bind water and emulsify fat which allows enhancing quality attributes of oil incorporated products. Thanks to this ability, they can improve texture and taste of some emulsion type product such as frozen dessert, and peanut butter. Moreover, they can give gel like structure and, increase water holding capacity, and the shelf-life. Furthermore, soy proteins have ability to provide viscoelastic texture, and to control viscosity of some drinks. Because of all these positive influence, byproduct of soy bean, especially soy protein isolates and concentrates started to be used as a commercial ingredient in many industries. For example, in supplement industry soy proteins are produced in tablet or capsule form; in bakery industry, they are used in production of functional foods such as bread, breakfast cereals, and bars, and in dairy industry, they are selected to improve functional properties of product. In addition to those functional abilities, to meet protein requirements, adding soy proteins to any food has showed a rising trend especially in developing countries (Majzoobi et al., 2014; Singh, Kumar, Sabapathy, & Bawa, 2008).

Rababah, Al-Mahasneh, & Khalil (2006) studied the effect of soy bean isolate, broad bean flour and chickpea flour on the sensorial and physicochemical attributes of biscuit. These flours and protein have been replaced with different ratios with wheat flour. Results indicated that soy protein fortification increased the darkness and hardness of biscuits

In another research, soy protein isolate was added to the cake of different ratios and influence of it has been analyzed in terms of quality of dough and cake (Majzoobi et al., 2014). At the end it was concluded that increasing soy protein isolate amount resulted in an increase in cake height and volume but a decrease in cake density. Finally, crust reached darker color in the presence of soy protein isolate.

1.4.5 Emulsifiers

Emulsifiers are the members of surfactants, in other words surface- active agents. They have both lipophilic and hydrophilic part; therefore they have ability to reduce surface tension of two immiscible fluids. They are used to increase dough strength, to achieve uniformity of cell size, to improve dough handling, to control rate of hydration, to reinforce water sorption, and to improve crumb structure, to reduce amount of fat and, finally to enhance gas retention. Emulsifiers can be categorized as nonionic which cannot dissociate in water, and ionic emulsifiers that can be classified as anionic and cationic. However cationic ones are not utilized in food applications. Hydrophilic -lipophilic balance number (HLB) index shows the proportional ratio of hydrophilic to lipophilic part in the emulsifier (Stampfli & Nerden, 1995). To obtain a desired emulsion system, HLB value has a great importance to select emulsifier with suitable physicochemical property. Low HLB value is contributed to lipophilic surfactants, and high HLB value refers to hydrophilic surfactants (Schmidts, Dobler, Guldan, Paulus, & Runkel, 2010).

The main role of emulsifiers in baking procedure is to provide enough gas bubble stability and required aeration until structure is formed. Incorporation of air into the batter is mainly dependent on mixing speed, surface tension of dough and viscosity. However, air retention ability depends on film forming capacity and speed of rising bubble in dough which viscosity of batter is mainly responsible. Interfacial characteristics of an emulsifier are responsible from covering the surface of newly formed gas bubbles to delay or stop coalescence. As a result, the quantity and type of emulsifier alter the bubble distribution and structure that are directly related to the final product quality (Sahi & Alava, 2003).

1.5 Rheological Properties of Cake Batter

Rheology is a discipline that studies the deformation and flow of the material under the effect of external force. In general to analyze rheological behavior of material, strain in other words deformation is applied to the material in a time interval and reaction is observed (or vice versa). These obtained data are the indication of properties like viscosity, modulus or stiffness of material. The purposes of measuring rheological behavior of material are to illustrate mechanical properties, to analyze molecular structure, and composition and to model behavior of material during processing. The most important reason for measuring this property for cake is that rheological feature of batter usually gives an idea about the final product quality like loaf volume and texture since batter handling properties are associated with rheological characteristics (Mudgil, Barak, & Khatkar, 2014). Many parameters such as shear stress, apparent viscosity, complex viscosity, loss and storage modulus and loss angle are the parameters commonly measured frequently in food systems (Saha & Bhattacharya, 2010).

In dynamic oscillatory test, sample is exposed to oscillatory stress strain frequency. The response of the sample is measured in terms of storage (G'), loss modulus (G''), and phase angle (δ). Solid like characteristic is symbolized by storage modulus G' which gets higher values for elastic materials. It is the indication of how much energy is stored. True elastic solids have ability to recoil back its original shape or position after removing of stress without losing energy, which is called as 100 % recovery of strain (Crockett, 2009). On the other hand, loss modulus G'' is more dominant in liquid like material that shows how much energy is dissipated (Saha & Bhattacharya, 2010).

Gel can be described as form of material that is between liquid and solid state. They are composed of a polymer molecules which are connected each one by cross links. These polymer networks are immersed in a liquid medium that is water for food systems. In weak gel formations generally $G' \geq G''$, and conjunction points are easily broken down even at low shear rates. For strong gel formations; $G' \gg G''$, both of them are independent of frequency (Saha & Bhattacharya, 2010).

Wheat batter has nonlinear viscoelastic ability and shows a non-Newtonian; shear thinning behavior. That is viscosity decreases with increasing shear rate. Wheat dough generally shows fluid like behavior under the effect of low shear rate; such as gravity. However, if higher shear rate is applied; it behaves like an elastic material which means turning back to its initial shape (Crockett, 2009). Viscoelastic behavior of wheat dough is due to gluten protein. Although viscous behavior comes from gliadin fraction, glutenin gives elastic ability to dough. Dough with high quantity of protein reaches a higher storage modulus values and lower tanδ (Mirsaeedghazi, Emam- Djomeh, & Mousavi, 2008). Like wheat batter; gluten free dough has tendency to flow with low shear rate. However, in contrast to wheat batter, gluten free dough flows at higher shear rate; so, permanent deformation is observed. That is the foremost characteristic of the gel, which is evidence of gluten free dough having a weak gel structure (Crockett, 2009).

To produce bakery product with high quality two main circumstances should be taken into consideration. The first one is that batter should have enough viscosity to prohibit rising gas cells and the second one is that dough should preserve its extensibility to conserve gas cell membrane elasticity and flexibility. There are many reasons that affect dough viscosity namely effect of air aeration, salt, surfactant, dry ingredients, and hydrocolloids. Higher water content leads to decreasing of storage and loss modulus inconsequentially. On the other hand, inadequate amount of water cannot meet the requirement of hydration of dry ingredients. Thus, dough structure cannot develop. Aeration of batter leads to more elastic behavior. Salt alters water interaction of components Fatty acid esters improve the extensibility of the dough and decrease the deformation resistance. Like fatty acid esters, whey protein also enhances the extensibility property and lowers storage and loss modulus. Addition of fat has a plasticizing influence and it suppresses viscous behavior (Mirsaeedghazi et al., 2008).

Turabi (2008) studied on the effect of usage of emulsifier and gum type on rheological properties of rice cakes. Many polymers that provide different elasticity to batter such as locust bean, Ꝁ- carrageenan, xanthan, guar gum, their blending, hydroxyl propyl methyl cellulose and Purawave TM were used. Casson model and power law model was used. Although batter containing HPMC had the lowest apparent viscosity, batter prepared with xanthan-guar blend and xanthan gum had the highest. Addition of emulsifier altered emulsion stability of batter (Turabi et al., 2008).

The effect of glucose oxidase enzyme on bread making quality properties such as quality of bread, protein modification, and batter rheology was investigated (Gujral & Rosell, 2004). It was proved that glucose oxide decreased amino group and thiol concentration. Moreover, it was revealed that viscous and elastic modulus had a tendency to increase with addition of glucose oxide According to a study conducted in 2010, effect of buckwheat flour types and ratios on gluten free bread formulation was investigated. Husked and unhusked buckwheat flour were combined to formulation at the concentrations of 10%, 20% and 30%. It was found out that breads prepared with both types of buckwheat had very similar rheological properties with wheat flour. Moreover, unhusked buckwheat flour had weaker protein structure, lower stability, and higher water absorption compared to bread with husked buckwheat. Up to some extend addition of husked type of flour increased both G' and yield stress, after this amount it led to decreasing of these values. On the other hand, increasing amount of unhusked buckwheat resulted in reduction of both G' and yield stress. Finally, firmness of breads increased with addition of both type of buckwheat flour.

In order to investigate different fibers on rice cake quality, guar gum, inulin and oat fiber were added to the formulation. Fiber addition generally increased viscosity of dough with the exception of inulin. Moreover, cakes prepared with oat fiber and inulin reached to higher specific volume. Finally cakes enriched with fiber had higher hardness value than control samples (Gularte, de la Hera, Gómez, & Rosell, 2012).

Demirkesen et al., (2010) examined the effect of chestnut flour concentrations and hydrocolloids (xanthan, xanthan- guar blend, and xanthan- locust bean gum) on rheology and bread quality. Herschel–Bulkley model was found as appropriate to describe flow behavior. Bread with 30% chestnut flour containing xanthan- guar blending had optimum quality. Increasing chestnut ratio had a negative influence on quality parameters

1.6 Studies on Gluten Free Baked Products

A study carried out by Turabi et al., (2008) examined the effect of gum types on macro and micro structure of rice cakes baked in both conventional and microwave oven (MW). In the study, xanthan, xanthan-guar blending, guar, κ-carrageenan, and locust bean gum were used. According to the study, cakes with xanthan and xanthan- guar combination gave the highest pore area fraction. Cakes baked in conventional oven had less porosity than ones baked in MW oven. Moreover, higher starch granule deformation was observed in cakes conventionally baked. Furthermore it was noted that number of pores and pore area fraction were affected by gum types.

In another research, staling of rice cakes prepared with guar gum, xanthan gum, and guar-xanthan combination were compared (Sumnu, Koksel, Sahin, Basman, & Meda, 2010). Gums were added at different concentrations and cakes were baked in two different type of microwave infrared combination oven (MW-IR) and conventional oven. It was concluded that guar- xanthan combination was more successful from the point of decreasing retrogradation enthalpy, weight loss and hardness value. Additionally, increasing gum concentration also reduced to retrogradation enthalpy, and moisture loss. Higher hardness value but lower retrogradation enthalpy was recorded in cakes baked in MW-IR combination oven.

The influence on buckwheat flour and lupin flour on quality parameters like volume, weight, hardness and color of gluten free cake was investigated (Levent & Bilgiçli, 2011). Buckwheat flour (20%) and lupin flour (40%) were substituted with rice and corn starch blend. Although minimum substitution of both buckwheat and lupin resulted in softer texture, higher replacement levels of buckwheat (15-20%) and lupin (30-40) led to an increase in hardness. Up to some extend; 20% lupin and 5% buckwheat flour replacement had a positive impact on volume of cake. While addition of buckwheat flour resulted in reduction in lightness and yellowness values of cake, lupin flour raised the darkness and yellowness values. Only 5% buckwheat substitution influenced the water retention capacity of cakes, therefore cake with 5% buckwheat had the lowest water loss.

Preichardt & Vendruscolo, (2011) investigated the quality of gluten free cakes prepared with different xanthan gum concentrations (0.2%, 0.3%, 0.4%). Cake without xanthan gum and cake with wheat flour were the controls. Usage of xanthan gum enhanced the specific gravity of batter and viscosity of batter, decreased hardness. Cakes with gum addition had more uniform internal structure since higher batter viscosity decreased the rate of gas bubble movement. Moreover, cakes prepared with xanthan gum had higher specific volume and it was observed that addition of xanthan decreased both firmness and staling. Furthermore, cakes formulated with 0.2% and 0.3% xanthan gum had similar characteristics with cakes prepared with wheat flour

Gularte, Gómez, et al. (2012) studied the effect of combination of different legume flours (lentil, pea, chickpea, and pea) on quality of gluten free cake. Addition of legume flours increased the batter viscosity. Except the cakes formulated with chickpea, cakes reached higher volume than control. On the other hand, legume flours affected the hardness and chewiness values of cakes adversely, with the exception of lentil. (Gularte, Gómez, et al., 2012).

In another study; carob bean flour was added to the gluten free bread formulation at different proportions (Tsatsaragkou et al., 2012). Water amount was also changed according to included carob flour amount. Textural and structural parameters such as firmness, porosity were analyzed. Fiber, mineral and protein amounts in samples were enhanced with the addition of carob flour, when utilized water amount was sufficient. It was found out that amount of water and carob flour amount in bread affected the porosity. While addition of water had a positive influence on porosity, carob flour had a negative effect on it. Fiber in flour interrupts protein network and decrease porosity and bread volume.

According to a study conducted in 2010, effect of buckwheat flour types and ratios on gluten free bread formulation was investigated (Torbica et al., 2010). Husked and unhusked buckwheat flour were combined to formulation at the concentrations of 10%, 20% and 30%. It was found out that breads prepared with both types of buckwheat had very similar rheological properties with wheat flour. Moreover, unhusked buckwheat flour had weaker protein structure, lower stability, and higher water absorption compared to bread with husked buckwheat. Up to some extend addition of husked type of flour increased both G' and yield stress, after this amount it led to decreasing of these values. On the other hand, increasing amount of unhusked buckwheat resulted in reduction of both G' and yield stress. Finally, firmness of breads increased with addition of both type of buckwheat flour.

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1.7 Objective of the Study

Celiac disease is an autoimmune disease that affects upper zone of small intestine. Remedy of this disease has not been found and people with celiac disease have to eliminate any food containing gluten from their diet. Therefore, wheat has to be replaced by any flour containing no gluten for celiac patients. However, without gluten some problems start to appear in products like less volume and poor texture since gluten has a unique ability to from viscoelastic structure and ability to retain gas bubbles inside the dough. Therefore, it becomes an obligation to use hydrocolloid or protein to mimic gluten behavior. Whey protein, by product of cheese industry, and soy protein can be regarded as good alternatives due to their emulsifying ability. In addition to them, polymeric substances like xanthan and guar gum that increase water holding capacity of batter and give viscoelastic ability to batter can be good alternatives to gluten. However, in the literature, there is no research that analyze the effects of hydrocolloids (xanthan gum- guar gum) and proteins (whey protein, soy protein) on gluten free cake rheology and final cake quality.

Celiac patients have to consume fortified products or food having high nutritional value. Carob bean flour and buckwheat flour are good alternatives for high nutritional foods. Both buckwheat flour and carob bean flour have high amount of dietary fiber and rich in minerals such as calcium, potassium, magnesium, and phosphorous. In addition, buckwheat has many health benefits such as inhibiting lipoprotein oxidation, reducing cholesterol, and increasing glucose tolerance. However, in literature, there is not any study about carob bean flour addition to gluten free cake formulations. Moreover, there is no search related to comparison of these two different kinds of flours with different concentrations in rice flour containing cakes in terms of their effect on quality parameters.

Therefore, the main objective of the study is to produce a high quality gluten free cake replacing two different gluten free flour (buckwheat and carob bean flour) with rice flour at different cocentrations (10%, 20%, 30%) using different gums/ proteins (xanthan gum, guar gum, soy protein and whey protein). The effects of flour, gum/ protein type on rheological behavior, and morphological characteristics of batter and also quality parameters (moisture loss, porosity, specific volume, hardness, color) of cake were studied.

CHAPTER 2

MATERIALS AND METHODS

2.1 Materials

For gluten free cake formulations rice flour, carob bean flour, and buckwheat flour were obtained from Başak Flour (Ankara, Turkey), Havancızade (Istanbul, Turkey, URL1), and Yar (Antalya, Turkey, URL1), respectively. Other ingredients such as salt (Billur Tuz, İzmir, Turkey), shortening (Sana, Unilever, Istanbul, Turkey), sugar (Bal Küpü, Aksaray, Turkey), and baking powder (Dr. Oetker, Izmir, Turkey) were purchased from local markets in Ankara. Egg white powder and emulsifier (Monoglyceride and polyglycerol esters of fatty acid) were obtained from ETI Food Industry Co. Inc. (Eskişehir, Turkey). Xanthan gum and guar gum were bought from Sigma-Aldrich (Steinheim, Germany and St. Louis, MO, USA). Soy protein concentrate containing at least 80% soy bean protein were obtained from Tito (Turkey, URL2) and whey protein concentrate with 80% purity were obtained from Göktürk (Turkey, URL2).

2.2 Methods

2.2.1 Procedure of Cake Preparation

Cake batter formulation was made of 5% baking powder, 3% salt, 100% sugar, 9% egg white powder, 25% shortening, 3% emulsifier, and 90% in terms of flour basis. That is, in control cake batter preparation for 100 g rice flour, 5g baking powder, 3g salt, 100g sugar, and 9g egg white powder, 25g shortening, 3g emulsifier, and 90g water were used. Carob bean flour and buckwheat flour at different concentrations (10, 20, and 30%) were added to the formulation by replacing rice flour. In order to see the effect of gum and protein, 1% xanthan gum or guar gum, 3% soy protein concentrate or whey protein concentrate were used interchangeably. Carob bean flour or buckwheat flour containing cakes without the addition of gum or protein were also used as control. The first step of preparation of cake batter was mixing. Dry ingredients (flour, sugar, salt, baking powder, and emulsifier) were mixed with a mixer (Kitchen Aid5K45SS, USA) for 2 min at 85 rpm. If soy or whey protein was used, it was also mixed with dry ingredients. Gum was dispersed in water by high speed homogenizer at 7200 rpm for 5 min (IKA T18Ultra-Turrax, Staufen, Germany). Melted shortening and gum suspension were added to the mixture and mixed further at stage 85 rpm for 5 min. Prepared batter was divided into 100 g portions and put in to 4 glass containers.

2.2.2 Physical properties of flours

Water holding capacity and particle size of flours were measured.

2.2.2.1 Water Holding Capacity

Flour (1g) was taken in 25 ml centrifuge tube. 10 mL of distilled water was added on it then it was hydrated for 1 h in a shaker at 130 rpm. After that, samples were centrifuged (10 min, 6000 rpm), the supernatant was discarded and residue was weighed. Water binding capacity of flour was expressed in terms of the amount of water absorbed per g dry sample.

2.2.2.2 Particle Size Distribution of Flour

Particle size distributions of both buckwheat and carob bean flour were measured using a set of U.S. standard sieves (18, 40, 60, 70, 80, 140, 270 mesh). 25 g of sample was used for sieve anlaysis. Weight of sample remained on each sieve was recorded after 5 min shaking time. Then using equation 2.1, 2.2 Sauter mean diameter (D_s) of flour particles was calculated.

$$\overline{D_{pi}} = \frac{D_{pi} - D_{p(i-1)}}{2} \qquad (2.1)$$

$$\overline{D_s} = \frac{1}{\sum_{i=1}^{n} \frac{X_i^w}{\overline{D_{pi}}}} \qquad (2.2)$$

where X_i^w; mass fraction of flour particles in a specific increment

$\overline{D_{pi}}$ =average particle diameter

2.2.3 Analysis of Cake Batter

Rheological properties, specific gravity of batter were analyzed and morphological analysis was carried out.

2.2.3.1 Rheological Measurement

Rheological behavior of cake batter was examined using a parallel plate rheometer (Kinexus dynamic rheometer, Malvern, Worcestershire, UK). The gap between the plates was fixed to 1 mm. To understand the flow behavior of batter, shear rate between 1-10 s^{-1} was applied and the corresponding shear stress data was obtained. As a first step of dynamic oscillatory experiments, linear viscoelastic region of batter was detected as strains ranging between 0.01% - 100% and at constant frequency of 1 Hz. After that, frequency sweep analysis was performed with changing frequency from 0.1 to 10 Hz with a constant strain rate of 0.1%. Finally, results were determined in terms of elastic modulus (G'), and loss modulus (G'').

2.2.4.2 Specific Gravity

Specific gravity measurement was carried out as described by Turabi, Sumnu, & Sahin, (2008). Certain volume of cake batter was weighed and divided weight of water at the same volume.

2.2.4.3 Morphological Characteristics of Batter

To analyze the morphological characteristics of gas bubbles formed during mixing, batters were displayed under light microscope. Very thin layer of prepared batters was smeared on glass microscope slides. Then, it was placed under the microscope (Primo Vert, Zeiss, Jena, Germany). Images were obtained with the help of microscopic camera (Sony CCD Color Digital Video C-Mount Microscope Camera, Tokyo, Japan) and analyzed using software namely TopView.

2.2.5 Baking of Cakes

For baking of cakes, an electrical oven (9411FT, Arçelik Inc. Co., Istanbul, Turkey) was used. Before starting the baking procedure, oven temperature was set to 175°C. After oven was preheated for 10 min, four glass cups each containing 100 g batter was placed into the oven. Baking operation took 28 min.

2.2.6 Quality Measurement of Cakes

Weight loss, porosity, color, texture, specific volume, macro and micro structure of cakes were the analysis that were used to measure quality parameters of cakes.

2.2.6.1 Weight loss

Weight of each sample in the glass cups were weighed before and after baking step. Weight loss in terms of percentage can be calculated using the equation (2.3).

$$\text{Weight loss} = \frac{W_{initial} - W_{final}}{W_{initial}} \times 100 \qquad (2.3)$$

$W_{initial}$ refers to weight of dough before baking, W_{final} represents the weight of cake after baking.

2.2.6.2 Porosity

Porosity of cakes was measured with compression method (Sumnu & Sahin, 2006). Immediately after baking process, cake was cut and placed into a cylindrical shape of container with 3 cm × 3 cm in both diameter and height.

Initial volume was calculated using these dimensions ($V_{initial}$, cm^3). After compression by applying 25N load for 2 min, with a new height of cake, final volume was calculated (V_{final}, cm^3). Porosity of sample was estimated by using equation (2.4).

$$\text{Porosity} = \frac{V_{initial} - V_{final}}{V_{initial}} \qquad (2.4)$$

2.2.6.3 Color

Color of crust part of the samples was measured using (Konica Minolta Spectrophotometer, CM-5, Japan). Results were evaluated in terms of CIE color coordinate system, (L^*, a^*, and b^*). ΔE^* denotes overall color change and it can be estimated using equation (2.5).

$$\Delta E^* = \sqrt{(L_0^* - L_0^*)^2 + (a_0^* - a_0^*)^2 + (b_0^* - b_0^*)^2} \qquad (2.5)$$

In this formula; L_0^*, a_0^*, b_0^* values are the reference values and obtained from the L^*, a^*, and b^* barium sulphate which were 93.2; -1.4; 0.12 respectively.

2.2.6.4 Textural Analysis

After being cooled down for 1 hour, two cakes were cut into cubic shape having dimensions of $3cm \times 3cm \times 3cm$ with a cylindrical probe having diameter of 1 cm and load cell of 50 N. To measure the hardness value of cakes texture analyzer (TA Plus Lloyd Ins., UK) was used. Force required to compress the sample 25% of its initial height with a compression speed of 55mm/min was measured.

2.2.6.5 Specific Volume Measurement

To measure the specific volume, rape seed displacement method was used (AACC, 1990).

2.2.6.6 Image Analysis of Cakes

Cakes baked were divided into two vertically. Cut side of one piece of cake was placed on glass of scanner (CanoScan, 3200F, Tokyo, Japan) and scanned with a scanning resolution 300 dpi.

To analyze porosity of cakes, the software (Image J URL) and the method that Impoco, Carrato, Caccamo, Tuminello, & Licitra, (2007) used were preferred. Firstly, each scanned images were cropped to eliminate artifacts at same cross section area. Then, they were converted to gray scale (8 bit) and pixel values were converted to mm by using bars with known length. After that, binarise operation was done to differentiate two phases (solid part and pores). Pore areas smaller than 0.5 mm^2 were not counted. Using analyze option pore area, pore size fraction and distribution were obtained.

2.2.6.7 Statistical Analysis

To decide whether there is a significant difference between flour types, concentartions, and hydrocolloids, analysis of variance (ANOVA) was carried out using MINITAB (Version 16). If there was a significant difference, Tukey multiple comparison test was used for comparison ($p \leq 0.05$). Baking was replicated twice for each cake formulation.

CHAPTER 3

RESULTS AND DISCUSSION

3.1 Physical and Morphological Properties of Cake Batter

The rheological properties of cake batter prepared by partial replacement of rice flour with buckwheat flour or carob bean flour at different concentrations and addition of gum/protein types were determined. Furthermore, specific gravity of batters was measured, and morphological characterization was determined.

3.1.1 Rheological Analysis of Cake Batters

Buckwheat containing cake batters showed shear thinning behavior (Figure 3.1-3.3). As can be seen in Figure 3.1, among the cake batters containing 10% buckwheat flour; xanthan and guar gum added ones had higher apparent viscosity. However, addition of xanthan gum had more influence on flow behavior of batter than guar gum. On the other hand, control samples and samples with soy, and whey protein had almost identical consistency. Flow curves of cake batter containing 20% buckwheat were shown in Figure 3.2. Apparent viscosity- shear rate relations between cake batter containing 20% and 10% buckwheat flour were very similar. Again, the highest value was owned by xanthan added batters, followed by guar gum containing ones. Moreover, there was no significant difference between protein containing, and control cake batter. Besides, 30% buckwheat flour added cake batters had similar flow curves with 10% and 20% concentrations.

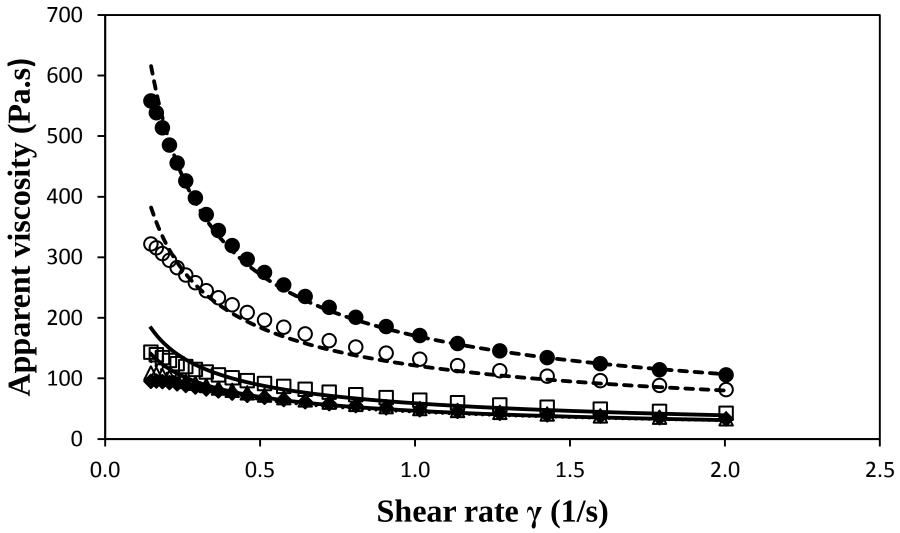

Figure 3. 1 Apparent viscosity of 10% buckwheat flour containing batters with different gum/ protein type: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦), model (---)

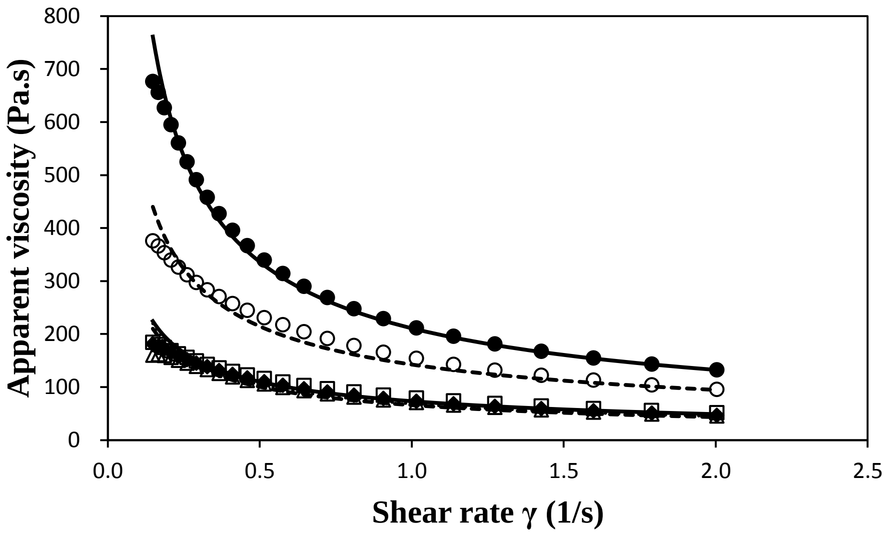

Figure 3. 2 Apparent viscosity of 20% buckwheat flour containing batters with different gum/ protein type: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦), model (---)

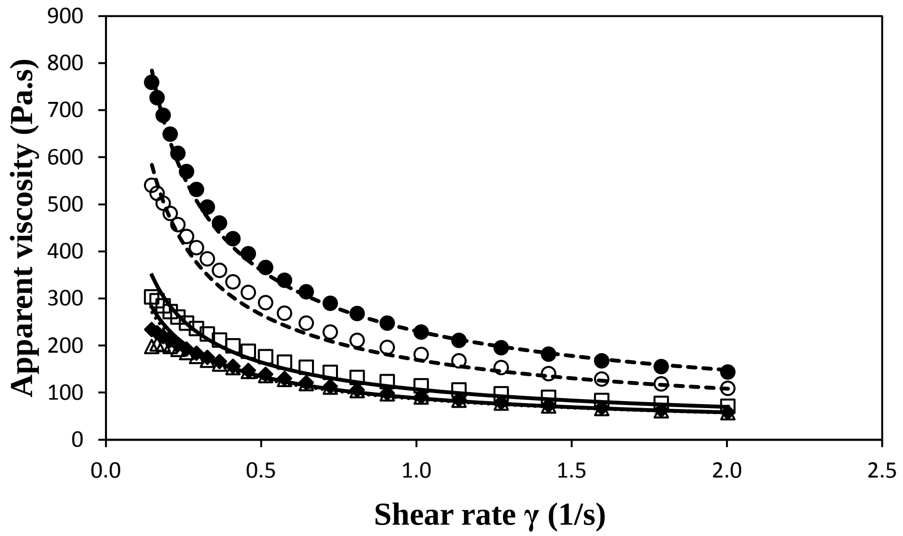

Figure 3. 3 Apparent viscosity of 30% buckwheat flour containing batters with different gum/ protein type: xanthan gum (●), guar gum (○), soy protein (□);whey protein (Δ), control (♦), model (---)

Power law constants of gluten free buckwheat added cake batters were shown in Table 3.1. Shear stress (τ, Pa) versus shear rate ($\dot{\gamma}$, 1/s) data were well fitted to Power law model (Eq 3.1);

$$\tau = K\,(\dot{\gamma})^n \qquad (3.1)$$

where K refers to consistency index (Pa.s^n), and n is flow behavior index.

Table 3. 1 Power law constants of buckwheat flour added cakes at 25°C

Buckwheat flour concentration (%)	Gum/ protein type	n	K(Pa.s^n)	R^2
10	Control	0.44 ± 0.009^{a}	44.63 ± 6.251^{ı}	0.99
10	Xanthan gum	0.32 ± 0.013^{e}	170.47 ± 4.157^{c}	0.99
10	Guar gum	0.39 ± 0.005^{abcd}	121.35 ± 1.158^{e}	0.99
10	Soy protein	0.40 ± 0.020^{abc}	59.00 ± 2.679^{hı}	0.98
10	Whey protein	0.42 ± 0.000^{ab}	46.60 ± 0.605^{ı}	0.99
20	Control	0.39 ± 0.003^{bcd}	68.62 ± 1.339^{gh}	0.99
20	Xanthan gum	0.32 ± 0.012^{e}	211.24 ± 1.852^{b}	0.99
20	Guar gum	0.40 ± 0.014^{abc}	142.53 ± 6.115^{d}	0.99
20	Soy protein	0.41 ± 0.003^{ab}	73.41 ± 2.112^{fgh}	0.99
20	Whey protein	0.39 ± 0.007^{bcd}	65.98 ± 1.977^{gh}	0.99
30	Control	0.40 ± 0.001^{abcd}	86.17 ± 1.607^{f}	0.99
30	Xanthan gum	0.35 ± 0.037^{cde}	230.88 ± 8.988^{a}	0.99
30	Guar gum	0.35 ± 0.003^{de}	169.74 ± 7.231^{c}	0.99
30	Soy Protein	0.38 ± 0.004^{bcde}	107.061 ± 4.789^{e}	0.98
30	Whey Protein	0.39 ± 0.000^{bcd}	83.371 ± 2.893^{fg}	0.99

Consistency index of batters changed from 44.63±6.251 to 230.88±8.988 $Pa.s^n$. On the other hand, flow behavior index values were in between 0.32±0.012 and 0.44±0.009. Since all flow behavior indices were lower than 1; all type of cake batter showed a shear thinning in other words pseudoplastic behavior (Table 3.1, Figure 3.1-3.3). Decreasing apparent viscosity with increasing shear rate was typical characteristic of pseudoplastic materials. As shear rate increased, material started to lose its resistance towards movement which took place because of disruption of aggregates and alignment of molecules in the direction of flow (Moser et al., 2013).

According to ANOVA (Table A.4) results; xanthan gum added cakes had the highest consistency index (Table 3.1). Similar results were obtained from the study conducted by Demirkesen et al. (2010). It was concluded that rice dough containing xanthan gum reached the highest consistency index value because of the complex aggregates developed by semi-rigid molecules. Besides, due to high water holding capacity of guar gum, available water that promotes movement of particles in cake batter decreases. Therefore, batters including guar gum had also high consistency value following xanthan added batters. Addition of soy protein to cake formulation also increased consistency index which might be due to disulfide bonds. On the contrary, whey protein addition decreased this value. This could be explained by the fact that more air incorporation during mixing had a decreasing effect on the consistency index.

Increasing buckwheat concentration resulted in increasing consistency index (Table 3.1). This might be due to increasing fiber content. Gularte, de la Hera, Gómez, & Rosell, (2012) stated that higher fiber content led to increasing consistency index value.

Similar to buckwheat flour added cake batters, carob bean flour added ones were also fitted to Power law model. Power law constants of carob bean flour added gluten free cake batters were shown in Table 3.2. Consistency index of the batters varied from 40.72±1.501 to 186.401±8.46 Pa.s^n. Furthermore, flow behavior index values changed from 0.28±0.017 to 0.44±0.007. Since all flow behavior indices were lower than 1, it can again be concluded that cake batter containing carob flour showed shear thinning behavior (Table 3.2, Figure 3.4-3.6).

Table 3. 2 Power law constants of carob bean flour added cakes at 25°C

Carob bean flour concentration (%)	Gum/ Protein type	n	K(Pa.s^n)	R^2
10	Control	0.44±0.007^{a}	40.72±1.501^{ı}	0,98
10	Xanthan gum	0.32±0.009^{ef}	173.52±1.178^{ab}	0,99
10	Guar gum	0.34±0.005^{cdef}	131.67±0.493^{d}	0,99
10	Soy protein	0.40±0.004^{abc}	55.81±0.801^{fgh}	0,99
10	Whey protein	0.42±0.013^{ab}	42.27±0.851^{hı}	0,99
20	Control	0.39±0.045^{abcd}	46.18±5.517^{ghı}	0,99
20	Xanthan gum	0.28±0.017^{f}	186.40±8.469^{a}	0,99
20	Guar gum	0.33±0.016^{cdef}	144.35±5.367^{cd}	0,98
20	Soy protein	0.36±0.002^{bcde}	62.64±0.141^{ef}	0,99
20	Whey protein	0.40±0.009^{ab}	51.41±1.990^{fghı}	0,99
30	Control	0.38±0.009^{abcde}	59.51±1.039^{fg}	0,99
30	Xanthan gum	0.33±0.018^{def}	159.20±0.292^{bc}	0,99

30	Guar gum	0.32±0.007[ef]	155.55±6.333[c]	0,98
30	Soy Protein	0.36±0.020[bcde]	76.12±1.991[e]	0,99
30	Whey Protein	0.33±0.005[cde]	59.85±4.748[fg]	0,99

According to two way ANOVA results; likewise buckwheat containing cake batter, xanthan gum added samples with carob bean flour had the highest consistency index value (Table A.4, Table A.9). Guar gum addition also enhanced this value but not as much as xanthan. Thus, these two gum containing samples were significantly different from each other. Furthermore; similar to buckwheat flour containing cake batter, addition of soy protein increased consistency index value of carob bean flour containing batter. The same effect of soy protein on dough rheology was also confirmed by many studies (Dogan, Sahin, & Sumnu, 2005; Nasiri, Mohebbi, Yazdi, & Khodaparast, 2010; Tiziani & Vodovotz, 2005). Moreover, rheological properties of control and whey protein containing batters were identical. In addition; increasing carob bean content increased consistency index value. Carob powder is generally used as natural sweetener in food industry since it includes high amount of sugar which binds water and influences rheology of batter. It was shown that non-starchy components of carob bean flour increased with increasing its concentration, which resulted in higher consistency index (Witczak, Ziobro, Juszczak, & Korus, 2015).

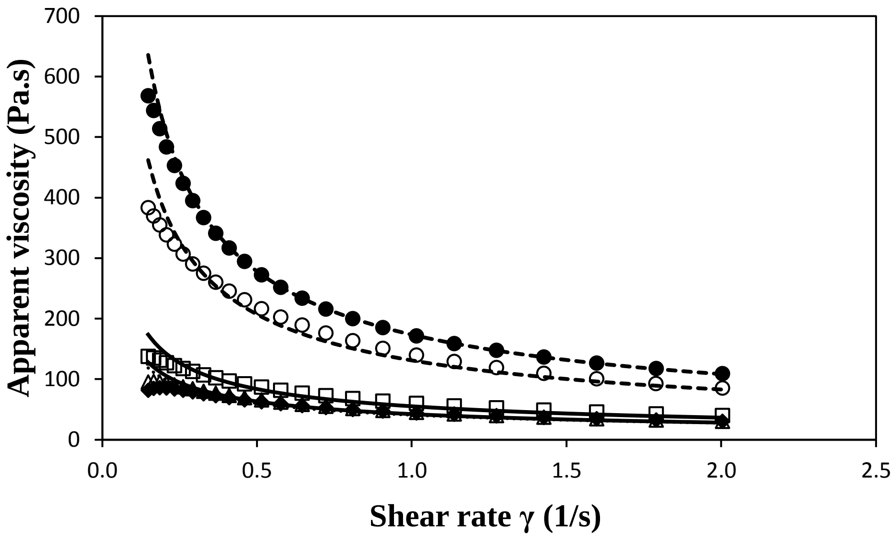

Figure 3. 4 Apparent viscosity of 10% carob bean flour containing batters with different gum/ protein type: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦), model (---)

As can be seen from Figure 3.4; cake batter formulated with 10% carob bean flour and xanthan gum had the highest apparent viscosity Batters with guar gum also had higher value following xanthan gum. Although addition of soy protein to formulation created the significant difference, whey protein addition did not affect the apparent viscosity significantly. That is cake batter formulations including whey protein had similar apparent viscosity value with control. Whey protein had low water holding capacity which might be the reason of why whey protein added batter and control had similar flow behavior (Damodaran & Paraf, 1997).

Furthermore, flow behavior pattern of 20% carob bean flour added cake batter was shown in Figure 3.5. The same trend was valid for xanthan gum and guar gum added samples.

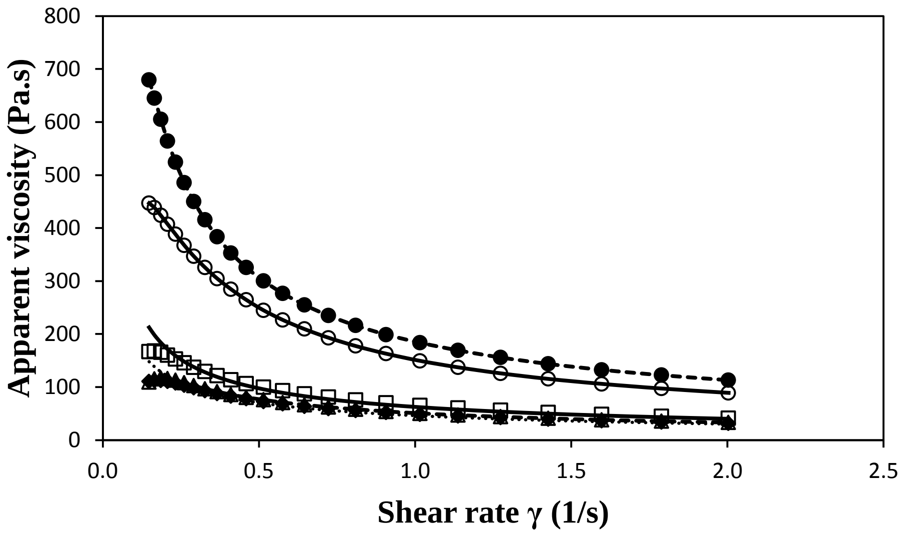

Figure 3. 5 Apparent viscosity of 20% carob bean flour containing batters with different gum/ protein type: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦), model (---)

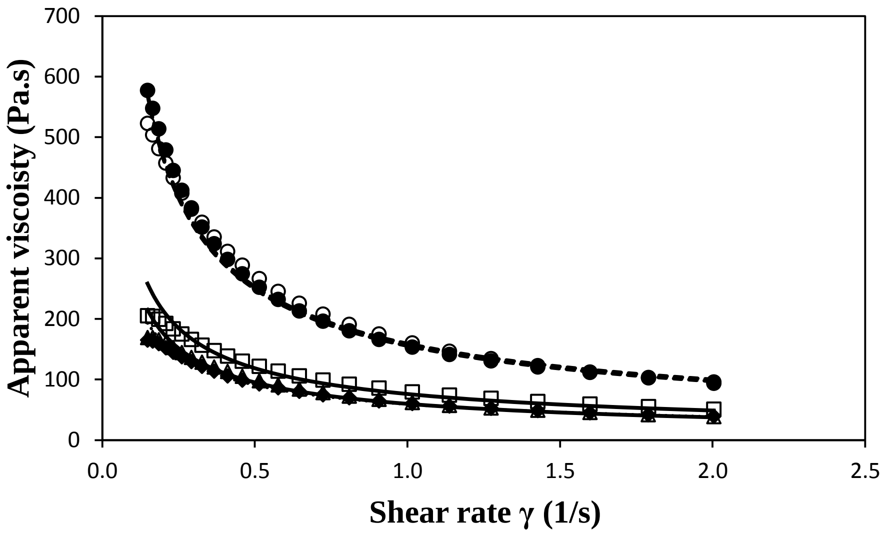

Figure 3. 6 Apparent viscosity of 30% carob bean flour containing batters with different gum/ protein type: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦), model (---)

Finally, flow curves of cake batter with 30% carob flour were shown in Figure 3.6. For this concentration, xanthan and guar added batters had similar apparent viscosity. Similarly, both whey and control batters had approximately the same apparent viscosity value.

According to three way ANOVA results, batters with buckwheat had higher consistency index value than carob bean added ones (Table A.11). This might be explained by their fiber content and solubility. In a study carried out by Milek et al. (2015), soluble fiber content of carob bean flour was recorded as 2.7% and insoluble fiber accounted 40% of flour composition. On the other hand, according to a research conducted by Skrabanja et al., (2004) soluble fiber and insoluble fiber amount in buckwheat flour were 3.1% and 1.4%, respectively. Although total fiber content of carob bean flour was higher, its soluble fiber content was less than buckwheat flour. Lecumberri et al., (2007) stated that due to higher hydration capacities of soluble fibers than insoluble ones, soluble fibers could easily hold water and swell to form a viscous solution. Water holding capacity results of flours supported this statement. While water holding capacity of buckwheat flour was recorded as 3.386±0.190 (g water/ g dry solid), that of carob bean flour was determined as 1.155± 0.042 (g water/ g dry solid). This might be the reason of higher consistency index values of buckwheat containing batters than carob bean flour containing one. Furthermore, according to Figuerola, Hurtado, Estevez, Chiffelle, & Asenjo, (2005), finer grinding of fibers might affect water holding capacity negatively by changing fiber matrix structure. Fiber size of carob bean flour might be smaller than that of buckwheat flour and this might be another reason for lower water hydration of carob bean flour. Moreover, regardless of type of flour, increasing flour content and addition of gum increased the consistency index.

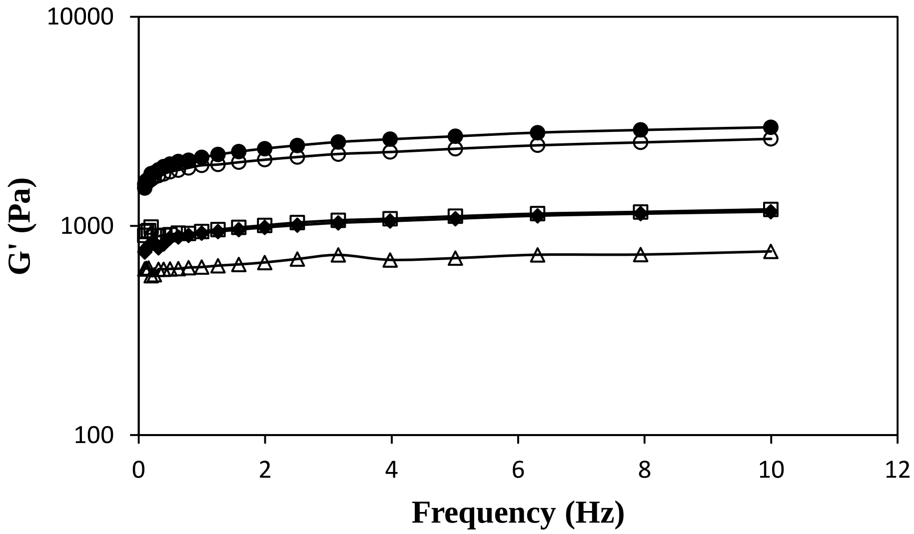

Figure 3. 7 Storage modulus (G') of batter samples containing 10% buckwheat flour: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦)

Figure 3.7 and 3.8 showed the storage and loss modulus of batters containing 10% buckwheat flour respectively. Batters with 20% and 30% buckwheat flour showed the same pattern with 10% added ones. Increasing modulus with increasing frequency was illustrated by figures which were the evidence of shear dependent moduli. However, gentle slopes of storage modulus were the indication of low dependency of modulus to frequency change. Furthermore, storage modulus of all samples was higher than loss modulus.

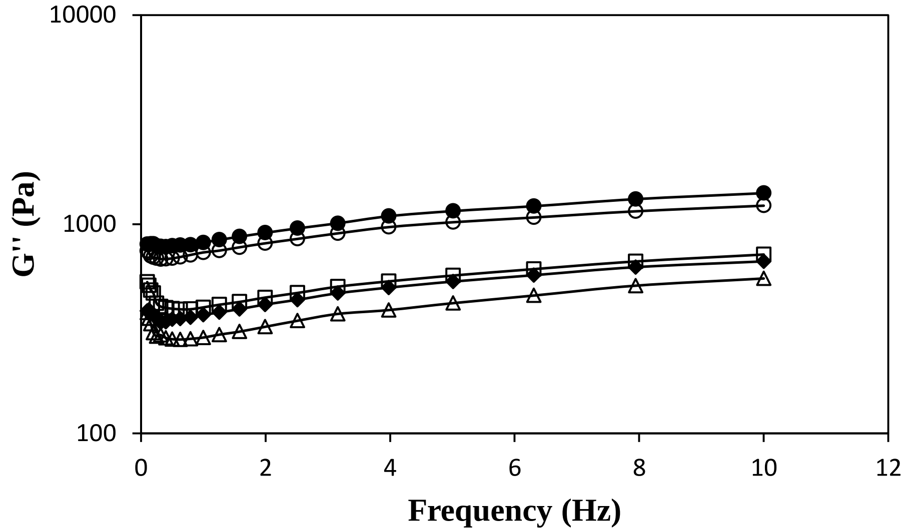

Figure 3. 8 Loss modulus (G'') of batter samples containing 10% buckwheat flour: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦)

Tan δ of all buckwheat added samples can be seen in Table 3.3. To estimate tan δ, ratio of loss modulus to storage modulus was calculated at constant frequency; 1 Hz (Peressini, Pin, & Sensidoni, 2011; Hesso et al., 2015). Tan δ of all batters was less than 1 which implied that samples showed gel like behavior. In literature, Hadnadev, Torbica, & Hadnadev, (2013), Sarabhai & Prabhasankar, (2014), Hesso et al., (2015) also found similar results and confirmed solid like behavior of gluten free batters and doughs.

Moreover, as can be seen from Figure 3.7 that addition of xanthan and guar gum had an enhancing effect on batter elasticity. Gum added samples had higher storage modulus than the others. This could be explained by self-association of gum even at low concentrations (Peressini et al., 2011). Another reason might be hydrocolloid-starch interactions which could be explained by attaching and enclosing of xanthan to starch granules.

Table 3. 3 Tan δ of buckwheat added batter at 25^{0}C at 1 Hz

Concentration	Gum/ protein type	Tan δ
10	Control	0.421^{bcd}
10	Xanthan gum	0.405^{bcd}
10	Guar gum	0.394^{bcd}
10	Soy protein	0.452^{abcd}
10	Whey protein	0.493^{abc}
20	Control	0.421^{bcd}
20	Xanthan gum	0.424^{bcd}
20	Guar gum	0.381^{cd}
20	Soy protein	0.494^{abc}
20	Whey protein	0.558^{a}
30	Control	0.469^{abcd}
30	Xanthan gum	0.410^{bcd}
30	Guar gum	0.361^{d}
30	Soy protein	0.461^{abcd}
30	Whey protein	0.503^{ab}

According to ANOVA (Table A.12) results, protein added samples had higher tan δ indicating more liquid behavior than gel like. On the other hand, gum addition decreased tan δ, which showed that solid like behavior became more dominant. Batter with guar gum was significantly different than control. Peressini et al. (2011) implied that if elasticity of batters increased excessively, it became difficult to corporate air into batter during mixing leading to lower quality. Therefore, it could be estimated that guar gum added samples would have the worst quality.

Figure 3.9 and 3.10 show the storage and loss modulus of cake batters prepared with 10% carob bean flour and with different types of gums and proteins. Variation of moduli of samples containing 20% and 30% carob flour with respect to frequency were very similar to batter with 10% carob bean flour. As can be seen in the figures, like buckwheat added samples, while frequency increased, both of the modulus values increased. However, slope of the graphs were almost constant which was an indication of less frequency dependency. Tan δ values of all carob bean added batters at 1 Hz were given in Table 3.4. As can be seen, all values were less than 1, showed a gel like behavior. According to ANOVA (Table A.13) results, gum added batters had significantly higher storage and loss modulus than control and samples containing protein. Furthermore, tan δ of gum containing ones was also lower than the rest showing more elastic characteristic. When the effects of proteins on viscous properties were compared, it was found that soy protein added batters had higher elastic property than whey protein added ones. Matos, Sanz, & Rosell, (2014) studied influence of different protein sources on rheological behavior of gluten free rice muffins and stated that addition of soy protein to the formulation decreased tan δ by increasing storage modulus. The effect of soy protein on batter rheology might be due to protein aggregation in the medium and potential action of two main globulins; β-conglycinin and glycinin by increasing disulfide bonding

(Crockett, Ie, & Vodovotz, 2015; Nammakuna, Barringer, & Ratanatriwong, 2015). It was argued that the effect of protein on rheology was dependent on its nature which might explain why whey protein added samples were not different than control. ANOVA results (Table A.13) pointed out that elastic behavior of batters increased with increasing carob bean concentration. This might be due to the increase in caroubin, a protein similar to gluten, found in carob bean flour.

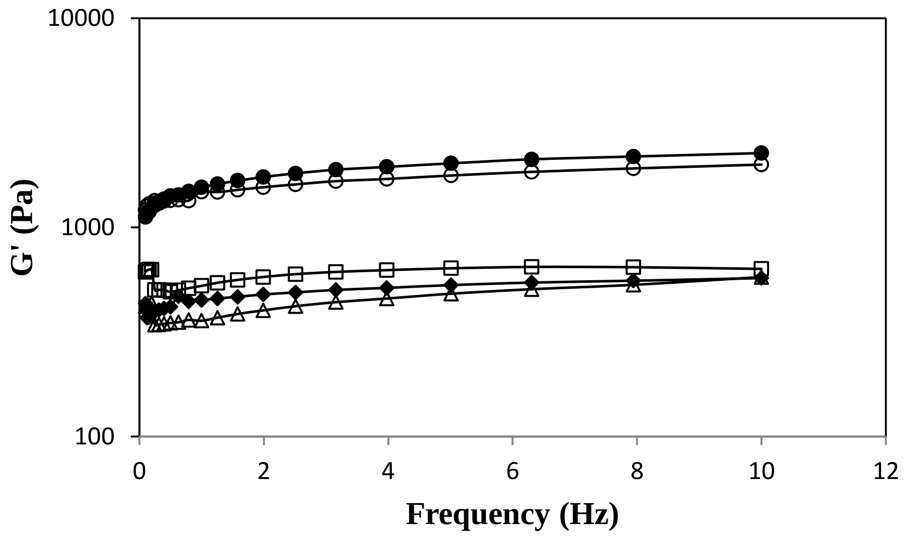

Figure 3. 9 Storage modulus (G') of batter samples with 10% carob bean flour: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦)

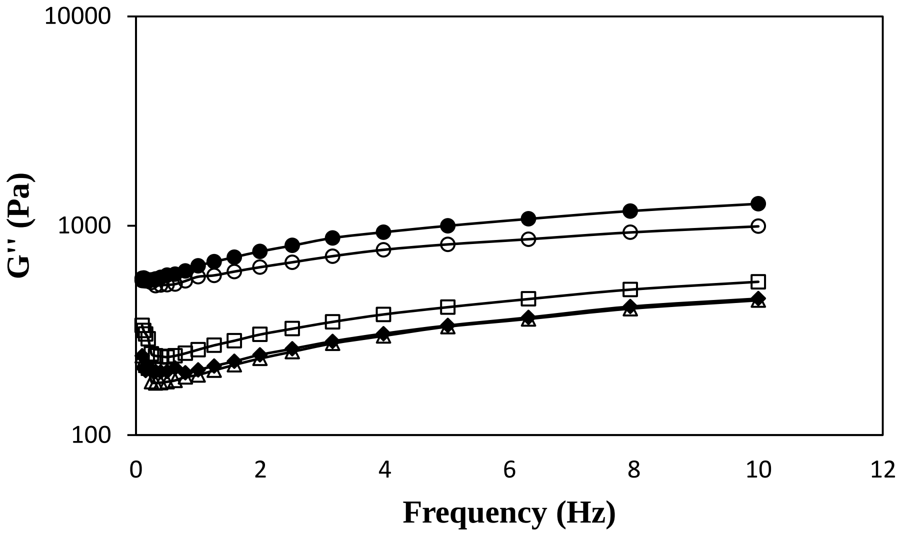

Figure 3. 10 Loss modulus (G'') of batter samples with 10% carob bean flour: xanthan gum (●), guar gum (○), soy protein (□); whey protein (Δ), control (♦)

Table 3. 4 Tan δ of carob bean added batter at 25^oC at 1 Hz

Concentration	Gum/Protein Type	Tan δ
10	Control	0.491^{bcde}
10	Xanthan gum	0.439^{defg}
10	Guar gum	0.406^{fgh}
10	Soy protein	0.529^{abc}
10	Whey protein	0.601^{a}
20	Control	0.560^{ab}
20	Xanthan gum	0.419^{efg}
20	Guar gum	0.377^{gh}
20	Soy protein	0.467^{cdef}
20	Whey protein	0.500^{bcd}
30	Control	0.507^{bcd}
30	Xanthan gum	0.379^{gh}

30	Guar gum	0.337[h]
30	Soy protein	0.392[gh]
30	Whey protein	0.379[bcd]

Three-way ANOVA results indicated that there was a significant difference between viscoelastic characteristics of batters prepared by two different flours (Table A.14). Batters containing buckwheat flour had more gel like behavior than carob bean flour added ones. This might be due to the difference between their water holding capacity values and fiber content.

3.1.2. Specific Gravity of Cake Batters

Specific gravity is a measurement of how much air is incorporated into batter during mixing. Therefore, lower specific gravity is an indicator of more aeration, which is a desired property for cake batter. Figure 3.11 represents specific gravity values of buckwheat added cake batters prepared with gums and proteins. Flour concentration, gum/ protein type and their interaction influenced specific gravity (Table A.19, Table A.24). As can be seen in Figure 3.11, cake batter containing 30% buckwheat flour and guar gum had the highest specific gravity which meant the least air incorporation. On the other hand, cake batter with 10% buckwheat flour and whey protein had the lowest specific gravity. According to ANOVA (Table A.19) results, guar gum added samples reached the highest, while whey protein added ones had the lowest value. This implied that the most efficient ingredient in terms of decreasing specific gravity was whey protein. Jyotsna, Manohar, Indrani, & Rao, (2007) recorded similar results about whey protein added cakes, and stated that cake batters with whey protein were lighter than the others which was related to good foaming ability of whey protein. Soy protein addition did not show the desired effect on specific gravity as whey protein did. This might be due to low solubility of soy proteins which was strongly related to foaming ability (Kinsella, 1979). According to two way ANOVA (Table A.19), both addition of xanthan gum and guar gum to the formulation resulted in higher specific gravity than control batters. This might be explained by higher apparent viscosity of batter which made air incorporation more difficult. On the other hand, control samples and rice cakes had similar specific gravity values like whey protein added batter. This might be due to the positive effect of emulsifier on aeration capacity (Khalil, 1998). Moreover, increasing buckwheat flour content in cake batter had a negative influence on specific gravity. Higher specific gravity values were recorded at higher buckwheat content since increasing fiber content might obstruct mixing efficiency and aeration of gas bubbles.

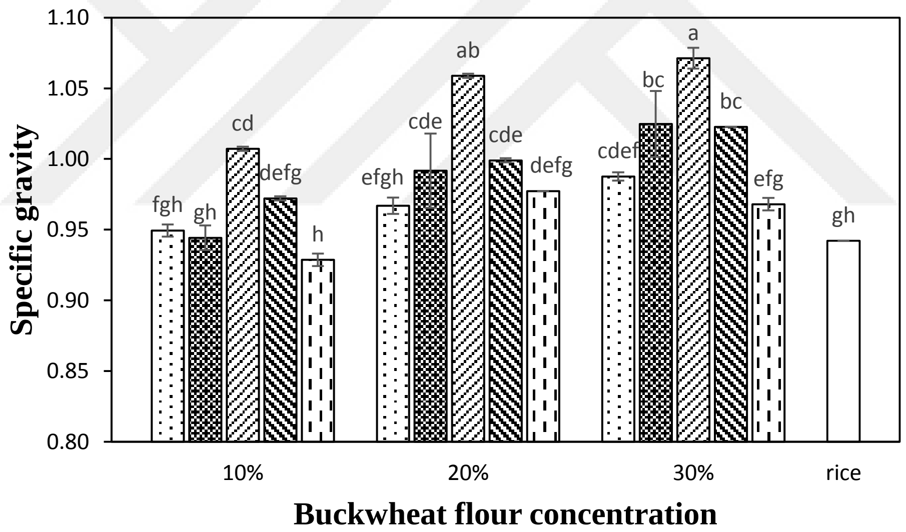

Figure 3. 11 Specific gravity of cakes prepared with different buckwheat flour concentration and gum/ protein type: control ( ), xanthan ( ), guar ( ), soy protein ( ), whey protein ( ), rice ( ). Bars having different letters are significantly different (p≤0.05).

The effect of carob bean flour addition, gum/protein type and their interactions on specific gravity of cake batter was shown in Figure 3.12. As can be seen, cake batter with 30% carob bean flour and guar gum had the highest specific gravity while 10% carob flour with xanthan added samples had the lowest. Cake batter containing 10% buckwheat without any gum or protein had similar specific gravity with rice cake batter. According to ANOVA results (Table A.9), guar gum addition resulted in increasing consistency index (Table 3.2) and apparent viscosity of cake (Figure 3.3- 3.5) batter which might make aeration of air into batter difficult. Due to low foaming property of soy protein, it was again not successful to decrease specific gravity of carob bean containing batters. In the presence of 30% carob bean flour, addition of xanthan gum and whey protein increased air bubble incorporation compared to control. Increasing carob bean amount in the formulation led to thicker batter (Table 3.2). The highest and the lowest specific gravity were measured when 30% and 10% carob bean flour were used, respectively.

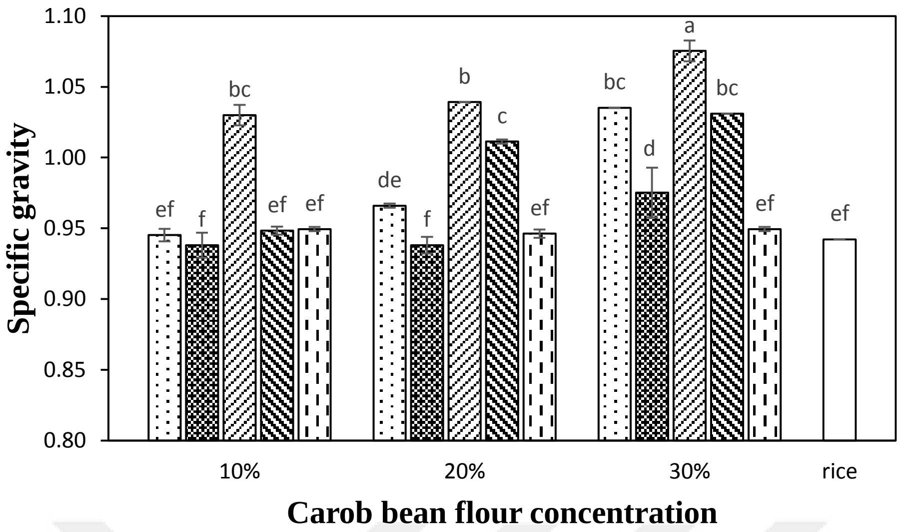

Figure 3. 12 Specific gravity of cakes prepared with different carob bean flour concentration and gum/ protein type: control (), xanthan (), guar (), soy protein (), whey protein (), rice ().Bars having different letters are significantly different ($p \leq 0.05$).

According to ANOVA (Table A.25) results; carob bean flour addition enhanced air incorporation leading to lower specific gravity compared to buckwheat flour. Therefore, flour type created a significant difference in terms of this parameter. Difference between protein content, and water holding capacity could be the reason of this result.

3.1.3 Morphological Analysis of Cake Batters

Optical images of batters containing 10% buckwheat flour were obtained using light microscopy. It was understood from Figure 3.13 that addition of protein and gum created some differences on batter morphology. As can be seen, cake batter with whey protein had more gas bubbles than control and guar gum containing ones.

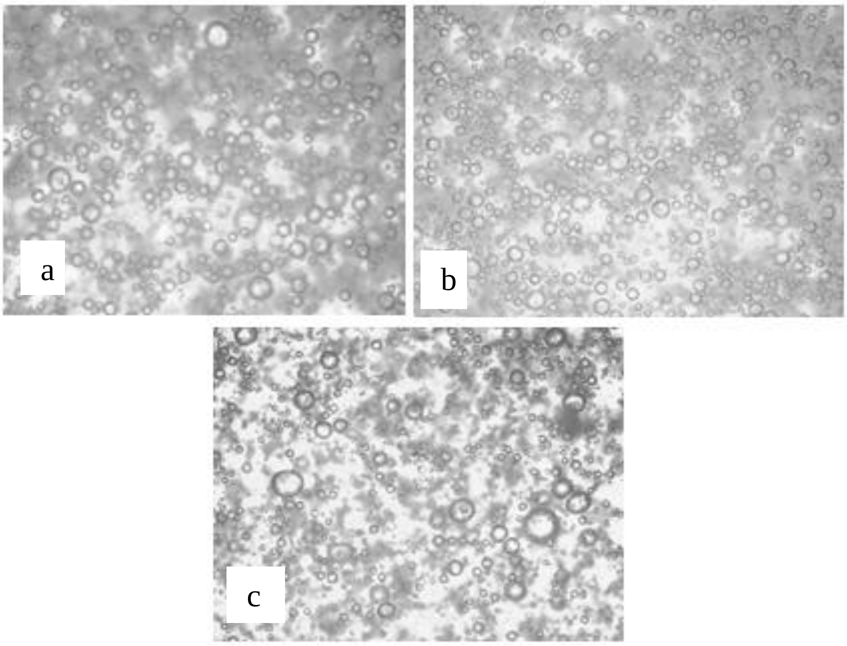

Figure 3. 13 Optical images of cake batters with 10% buckwheat (magnification 4×) control (a), whey protein (b), guar gum (c)

More uniform distribution of gas cells was observed in whey protein containing samples compared to other batters. Size of gas cells present in whey protein added batter could be estimated as medium and small. On the other hand, cake batters prepared with guar gum had less number of gas bubbles compared to others. Moreover, these bubbles were either big or small in size and unevenly distributed. These image analyses were supported by both rheology and specific gravity results. As discussed before, cake batters containing whey protein had the lowest specific gravity which meant more air incorporated into batter during mixing. This was due to good emulsification ability of whey proteins. Therefore, due to high number air bubbles in whey added batters, those samples may result in high quality of gluten free cake. On the other hand, as seen in rheology results, batter formulated with guar gum showed the most solid like behavior which obstructed aeration of air to batter leading to the lowest number of air cells. As can be seen from the Figure 3.13, guar gum added batters had the fewest number of gas bubbles with non-homogenous gas bubble size distribution.

3.2 Quality of Cakes

Effects of partial replacement (10%, 20%, 30%) of rice flour with buckwheat and carob bean flour, and addition of different types of gums and proteins on quality parameters of gluten free cakes were determined. Weight loss, porosity, specific volume, hardness, color and image analysis of cakes were investigated.

3.2.1 Weight Loss

Baking is a process that involves both heat and mass transfer. While heat is transferred through the cake, it leads to vaporization of moisture from the surface, which results in weight loss of samples. Since moisture loss increases the hardness of cakes, to decrease it; flour with high fiber and starch content can be preferred and hydrocolloids can be added in cake formulations. Weight loss of cakes containing different concentrations of buckwheat flour was shown in Figure 3.14. Lower weight loss was observed, when buckwheat concentration was increased due to dietary fibers present in buckwheat (Mariotti et al., 2013). Addition of 10% buckwheat flour to cake was not sufficient to keep the moisture in the system. Increasing buckwheat flour concentration which means increase in dietary fiber and starch amount resulted in decrease in weight loss of cakes (Table A.30). Qian, Rayas-Duarte, & Grant, (1998) reported that water binding capacity of buckwheat starches were higher than corn and wheat starch. This is due to the fact that buckwheat has smaller size of starch granules which leads to higher surface area. During baking, crystalline structure of starch granules start to disrupt and absorb water which result in swelling of starch granules. This acts as a barrier and prevents moisture loss, which results in less weight loss of samples (Xue & Ngadi, 2006). Furthermore, 10% replacement of rice flour with buckwheat flour without any gum/protein did not change weight loss of cakes as compared to the cakes containing only rice flour. In general, it was stated that gums could weaken the starch structure and lead to more uniform water distribution and better water retention (Kohajdová & Karovičová, 2009). This could explain why gum added samples had lower weight loss. In additionally, xanthan and guar gum containing samples resulted in different weight losses. Gomez, Ronda, Caballero, Blanco, & Rosell, (2007) also showed that cakes prepared with different hydrocolloids including sodium alginate, pectin, locust bean gum, xanthan gum and guar gum had less moisture loss than control during baking process. Moreover, this study also indicated that different hydrocolloids led to different weight loss due to the difference in their water retention abilities depending on their chemical structure.

In addition to nutritional aspect of soy protein isolate, due to its water holding ability, it was used in cakes, breads and macaroni to decrease moisture loss (Singh et al., 2008). Cake containing 10% buckwheat and soy protein had lower weight loss than control. On the other hand, for cakes containing higher amount buckwheat flour, soy protein did not create significant difference. When the concentration of buckwheat flour increased, flour characteristics became more dominant than the soy protein in moisture retention. Furthermore, it is known that high water soluble milk proteins such as whey proteins are less efficient than insoluble one, casein, in terms of moisture retention. Although water retention ability of proteins increases with denaturation, whey proteins are not good at retaining moisture in cake still after baking (Okun , et al., 2004). Thus, this could be the reason of in significant effect of whey protein on weight loss of cakes when 20% or 30% of rice flour was replaced with buckwheat flour.

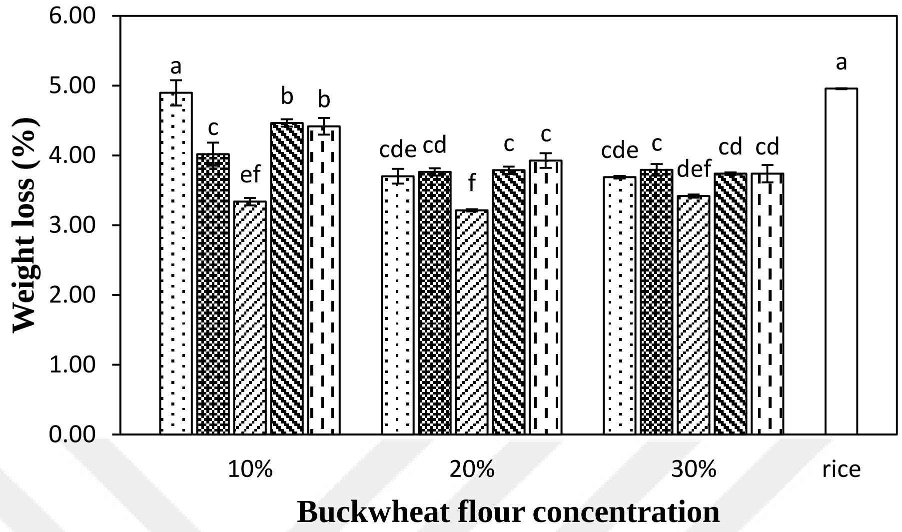

Figure 3. 14 Weight loss of cakes prepared with different buckwheat flour concentration and gum/ protein type: control (), xanthan (), guar (), soy protein (), whey protein (), rice flour (). Bars having different letters are significantly different (p≤0.05).

Weight loss of cakes prepared with carob bean flour was shown in Figure 3.15. Cakes containing carob bean flour had lower weight loss than only rice flour containing cake, meaning that carob bean flour were more efficient in retaining water inside the cakes due to its fiber content. Although the particle size, ratio of dietary to in-dietary, type, amount, origin of fiber have an influence on water absorption (Cauvain, 2003), due to hydrophilic nature of fiber in carob flour, weight loss might be decreased, especially in cakes formulated with 30% concentrations. According to ANOVA (Table A.35) results, cakes with 30% carob bean flour concentration had lower moisture loss than 10% and 20% containing ones. Similar to buckwheat flour, lower moisture loss at higher carob bean flour concentrations might be due to increasing fiber content and starch content. A study carried out by Milek et al. (2015) supported that moisture retention capacity and water absorption ability were directly related to fiber content in food and carob flour could be classified as high fiber content flour. Similar to cakes containing buckwheat flour, among the carob bean flour cakes, higher weight loss was observed in control cakes and cakes with whey protein. This result also supported that whey proteins did not have water retention ability. In general, gums (xanthan and guar gum) were more efficient in water retention, since cakes with gums had lower weight loss. Cakes with guar gum had always the lowest moisture loss regardless of carob bean flour concentrations. This was due to the strong water holding ability of it.

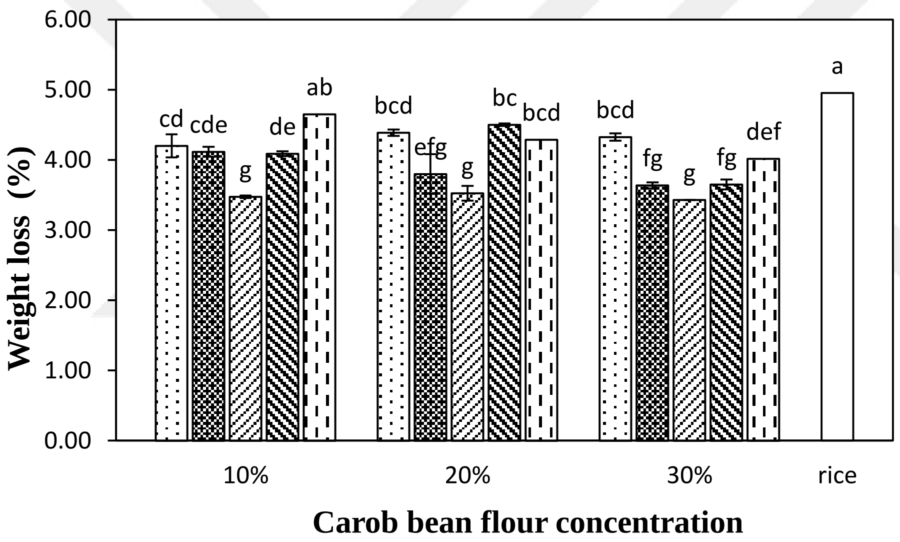

Figure 3. 15 Weight loss of cakes prepared with different carob bean flour concentration and gum/ protein type: control ( ), xanthan gum ( ), guar gum ( ), soy protein ( ), whey protein ( ), rice flour ( ).Bars having different letters are significantly different (p≤0.05).

Among these two different flours, carob bean flour had higher moisture loss than buckwheat flour (Table A.36). This might be due lower water holding capacity of carob bean flour compared to buckwheat flour. Furthermore, usage of 10% of those flours in cake formulation was not as successful as 20% and 30% addition in terms of retaining moisture. While whey and soy proteins did not create a significant difference to prevent moisture loss and had similar weight loss with control cakes, gums especially guar gum succeeded in retention of moisture loss.

3.2.2 Porosity

Air incorporation during mixing and entrapment of carbon dioxide bubbles during baking are mainly responsible from the cake porosity. Specific gravity and apparent viscosity of cake batter are two important parameters that affect incorporation and entrapment of gas bubbles. While specific gravity became important physical property to decide how much air was incorporated in cake batter, the latter one gained importance to prevent escaping, raising or early collapse of carbon dioxide produced by baking powder.

Porosity distribution of buckwheat added cakes with different concentrations was shown in Figure 3.16. Porosity results showed that increasing the amount of buckwheat flour had a negative effect on porosity.

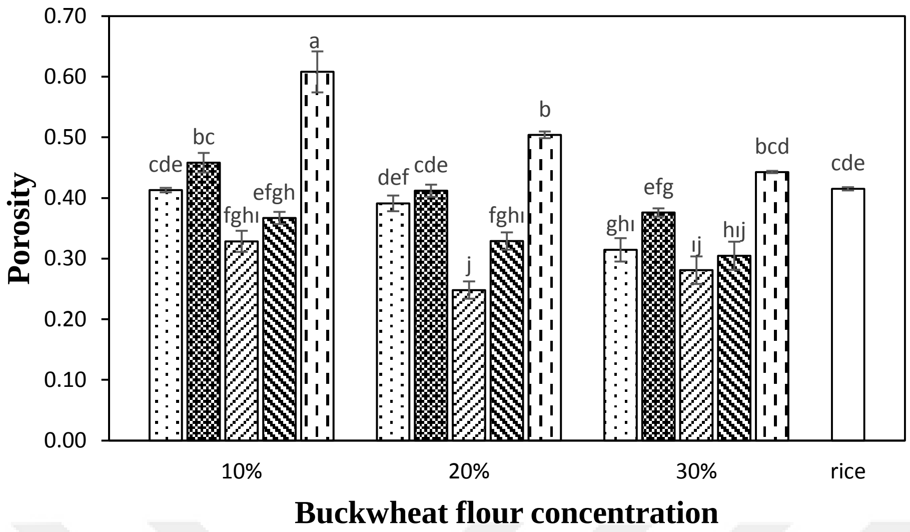

Figure 3. 16 Porosity of cakes prepared with different buckwheat flour concentration and gum/ protein type: control ( ), xanthan ( ), guar ( ), soy protein ( ), whey protein ( ), rice flour ( ). Bars having different letters are significantly different ($p \leq 0.05$).

While buckwheat flour concentration increased, porosity values of cakes decreased (Table A.41). According to two way ANOVA results, the highest porosity was observed in cakes containing 10% buckwheat flour. Cakes prepared with whey protein had the highest porosity among all buckwheat flour containing cakes. On the other hand, guar gum added cakes had the lowest value even lower than control. These results were in good agreement with specific gravity (Table A.19- Table A.24). Lower specific gravity implies higher air incorporation of air in cake batter during mixing. Therefore, high amount of air entrapped samples had higher porosity after baking which was supported by higher correlation between specific gravity and porosity with coefficient of -0.797 (p=0.000). Rice cake had the same porosity with 10% and 20% buckwheat flour containing cakes when no gum/protein was used. Increasing the buckwheat flour concentration to 30% reduced porosity of cakes significantly.

Proteins are regarded as emulsifiers, surface active compounds, which helps reducing and preventing coalescence of gas bubbles (Sahi & Alava, 2003). Whey proteins are known to be good surface active agents with good emulsifying ability. Because of this property and good foaming ability, cakes containing whey protein had lower specific gravity (Figure 3.11). This is the reason why cakes with whey proteins had always higher porosity.

Although gums do not have any emulsifying ability, cakes prepared with xanthan gum also had lower specific gravity and higher porosity (Table A. 19, Table A.41, and Figure 3.16). Mode of action of gums on porosity could be different than that of proteins. Gums mimic the gluten behavior, increase viscosity, give viscoelastic property to batter, and prevent rising of gas bubbles through the surface during baking. This leads to higher porosities of cakes. Turabi et al., (2010) observed similar results in gluten free rice cakes. It was stated that cakes prepared with xanthan and xanthan-guar blend had higher porosity than cakes containing other gums which was related to higher apparent viscosities of these cake batters. Cake batter with xanthan gum had the highest apparent viscosity. Thus, higher porosity value was measured for these batters (Table A.41).

During baking process, viscoelastic cake batter can be converted to porous solid structure gradually due to gelatinization of starch and coagulation of protein. These two physico-chemical changes strongly depend on type and origin of both protein and starch. Sugar, protein and other ingredients such as gums are factors affecting starch gelatinization. For example, sugar increases gelatinization temperature and delay gelatinization of starch, since sugar decreases water activity or available water for gelatinization. While the bound water amount increases, gelatinization temperature also increases (Spies & Hoseney, 1982). In addition, proteins form some complexes with starch granules and bind surfaces of starch which delay gelatinization and increases temperature for this process

(Bayındırlı, Sumnu, & Ndife, 1999). If required temperature for gelatinization is achieved later, transition of batter from viscoelastic to solid structure occurs later. This allows more time for forming of CO_2 and obtaining more porous structure (Majzoobi et al., 2014). Therefore, due to the effect of sugar and protein content on starch gelatinization, cakes with whey protein and xanthan gum had higher porosities.

Soy protein did not have similar impact on porosity as whey protein. The first reason for that might be the solubility of soy protein. Solubility is known to be related to foaming ability (Kinsella, 1979). A research carried out by Malhotra & Coupland, (2004) indicated that although exact emulsifier-protein interaction were still unknown, surfactants could affect solubility of protein. Thus, emulsifier- soy protein interaction might also be another factor in decreasing solubility, in other words foaming ability of soy protein (Malhotra & Coupland, 2004). In addition, soy protein might decrease surface tension of emulsion gradually as its amount increased (Kinsella, 1979). Therefore, the amount of soy protein used in cake formulation might be less than the required amount.

Although guar gum was used for the same purpose with xanthan gum, it did not have the same impact on porosity as xanthan gum did. This might be explained by specific gravity. Specific gravity of guar gum containing batters were higher than xanthan gum. Therefore, during mixing, enough air could not be entrapped in batter in the presence of guar gum. Although addition of guar gum increased apparent viscosity of cake batter as xanthan gum did this ability was not sufficient alone to get highly porous structure. Furthermore, in contrast to xanthan gum containing cakes, considerable increase in viscoelastic property (Table A.12, Table A.13) of cake batter with guar gum made incorporation of air more difficult as compared to control. This might be the reason of having lower porosity in guar gum containing cakes than control. Moreover, created gas bubbles might be unstable and could not be kept in the system for a long time.

As can be seen Figure 3.17, higher porosity values were measured in cakes containing 10% carob bean flour than the ones with higher flour concentrations (Table A.46). Similar results was observed in a study carried out by Tsatsaragkou et al.(2012). Increasing carob bean flour concentration resulted in increasing fiber content of cakes also. Thus, fibers might disturb the protein arrangement and resulted in reduction in porosity. Furthermore, for all concentration of carob bean flour, cakes with whey protein had the highest porosity value. Likewise in samples containing buckwheat flour, there was a good agreement between specific gravity and porosity values with correlation coefficient of -0.744 (p=0.000). This meant that lower specific volume with high air incorporated samples had higher porosity.

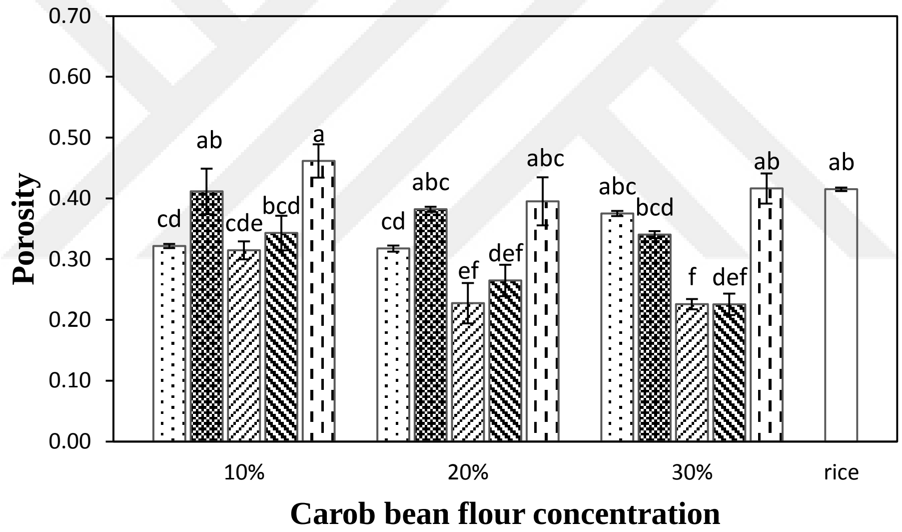

Figure 3. 17 Porosity of cakes prepared with different carob bean flour concentration and gum/ protein type: control ( ), xanthan gum ( ), guar gum ( ), soy protein ( ), whey protein ( ), rice flour ( ). Bars having different letters are significantly different (p≤0.05).

Three way ANOVA (Table A.47) results showed that cakes with buckwheat flour had higher porosity than carob bean flour containing ones. Amylose content had an effect on starch gelatinization temperature. Starch with high amylose content lowers gelatinization temperature. Carob bean flour may contains high amount of amylose, which decreases gelatinization temperature, and transition from semi-solid phase to solid phase may occur faster. Therefore, less porous structure was obtained (Sasaki, Yasui, & Matsuki, 2000). Protein content of flours might be another affecting porosity. Miñarro, Albanell, Aguilar, Guamis, & Capellas, (2012) carried out experiments with chickpea, pea isolate, carob germ flour, and soy flour. It was stated that because of different amino acid content, bread with chickpea had higher loaf expansion than others since chickpea protein provided more stable foam. Therefore, amylose content and protein type could be the factors that had influence on porosity.

3.2.3. Specific Volume

Volume of cakes is one of the most important quality attribute for consumer. Specific volume of cakes with buckwheat flour and different gums and proteins was shown in Figure 3.18. Specific volume of cakes varied between 1.41 and 1.98 ml/g and positively correlated with porosity values, 0.881 (p=0.000). As can be seen from the Figure 3.18 and ANOVA results (Table A.51), cake with only rice flour had higher specific volume than many cakes with buckwheat flour which might be due to effect of emulsifier. Seyhun, Sumnu, & Sahin, (2003) stated that emulsifier helps formation of incorporation of air bubbles during mixing. Emulsifier dispersed in shortening in the form of small particles which provides many number of gas cells. This may be the reason of rice cake with high specific volume. According to ANOVA (Table A.52), specific volume of cakes with 20% and 30% buckwheat flour were not significantly different. On the other hand, cake prepared with 10% buckwheat flour had significantly higher specific volume than 20% and 30% buckwheat flour containing ones. Increasing buckwheat flour content in cake formulation might make incorporation of air in cake batter difficult due to higher fiber content. This resulted in decreasing specific volume of cakes with increasing buckwheat flour content. This approach was also supported by higher specific gravity of cakes with increasing buckwheat content (Table A.19). As supported by specific gravity and porosity results, cakes with whey protein had the highest specific volume (Figure 3.18, Table A. 19, and Table A.41). A study conducted by Nunes, Ryan, & Arendt, (2009) had similar outcomes. It was stated that addition of whey protein to gluten free bread formulation led to improvement of specific volume. In addition, it was remarked that whey proteins were one of the globular proteins with great thermal gelling ability. During baking process, these proteins start to denature and bonds responsible from tertiary structure of protein are destroyed at temperatures higher than 70^{0}C. After protein becomes unfolded, new protein-protein interactions and interactions with other ingredients present in cake batter begin to form. These newly constructed interactions might be the reason of increasing specific volume of bread. Furthermore, control cakes, cakes with xanthan and soy protein had similar specific volume. Gularte, de la Hera, Gómez, & Rosell, (2012) reported that apparent viscosity of batter was closely related to retaining gas bubbles capacity during baking. However, it was also argued that excessive increase in apparent viscosity might restrict the batter expansion (Gularte, de la Hera, et al., 2012). Lazaridou, Duta, Papageorgiou, Belc, & Biliaderis, (2007) also found out that addition of xanthan to gluten free bread formulation led to decreasing volume of cakes. On the other hand, in studies carried out by Kohajdová & Karovičová, (2009); and Preichardt & Vendruscolo, (2011) it was found that xanthan gum improved volume of cake. For this study, xanthan addition neither increased nor decreased specific volume of cakes. Similar to xanthan, soy protein added samples had similar volume with control cakes. A study conducted by Ziobro & Witczak, (2013) revealed that bread prepared with soy protein had lower volume and similar porosity with control, too. Furthermore, Matos, Sanz, & Rosell, (2014) reported that muffin volume were significantly affected by protein type and stated that volume of vegetal origin protein (soy protein isolate, pea protein isolate and vital wheat gluten) added samples were not significantly different from control (no protein added). On the other hand, animal source proteins improved muffin volume. Because of this reason soy protein and whey protein added cakes were significantly different from each other. Control cakes of buckwheat flour had considerable high specific volume due to high dietary fiber content, emulsion forming stabilizing ability of globulin proteins, gelling and swelling character of buckwheat (Mariotti et al., 2013). Moreover, cakes with guar gum had the lowest volume. As can be seen in Table A.12, Table A.13, guar gum added formulations had more solid like behavior than all other samples which made air corporation to batter difficult, which was also supported by the highest specific gravity results (Figure 3.11, Figure 3.12). Higher apparent viscosity of batters can generally be interpreted as successful to prevent rising of gas bubbles. Besides, batters with guar gum did not have high consistency index as much as batters with xanthan gum (Table A.4, Table A.9) which meant that guar gum was not as sufficient as xanthan gum in gas retention. Besides, different effects of gums on specific volume and hardness could be explained by distinct gums-starch interaction and their influence on retrogradation.

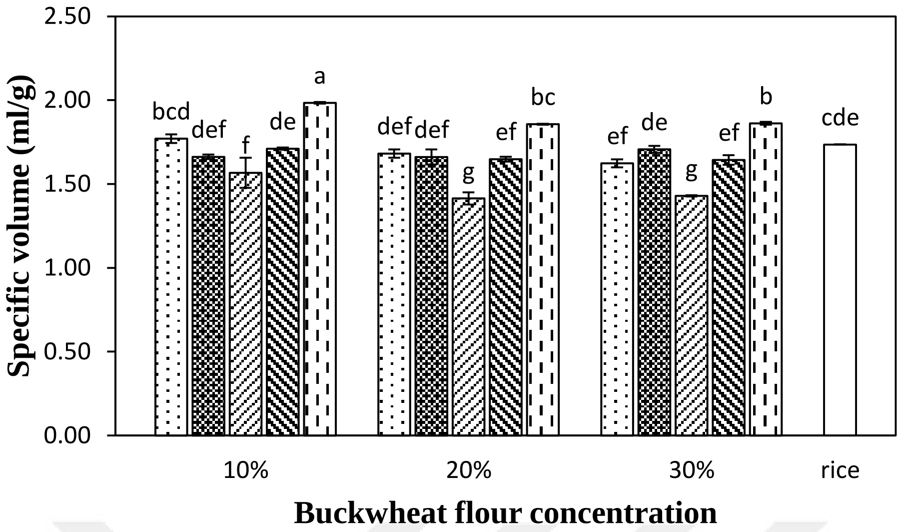

Figure 3. 18 Specific volume of cakes prepared with different buckwheat flour concentration and gum/ protein type: control (⬚), xanthan (▩), guar (▨), soy protein (▧), whey protein (⬚), rice (☐). Bars having different letters are significantly different (p≤0.05).

The specific volume of cakes prepared by carob bean flour with different concentrations and different gum/protein type was shown in Figure 3.19. Specific volume of cakes changed between 1.47 and 1.98 (ml/g). The highest volume was obtained by adding whey protein to cakes with 20% carob bean flour. The lowest volume was achieved in guar gum added and 30% carob bean flour containing one. Correlation coefficient between porosity and specific volume was found as 0.763 (p=0.000).

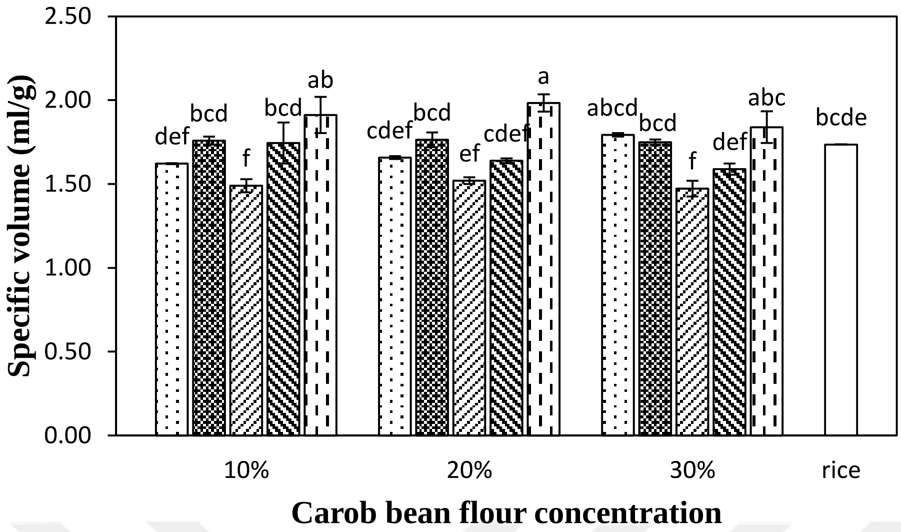

Figure 3. 19 Specific volume of cakes prepared with different carob bean flour concentration and gum/ protein type: control (), xanthan (), guar (), soy protein (), whey protein (), rice (). Bars having different letters are significantly different (p≤0.05).

For all concentrations of carob bean flour, whey protein added samples had the highest specific volume, while cakes with guar gum had the lowest specific volume. ANOVA (Table A.57) results revealed that changing carob bean flour content was not significantly effective on volume of cakes. It means that gum/protein type and interaction between flour played an important role on this parameter. However, Smith, Bean, Herald, & Aramouni, (2012) reported that increasing carob bean flour concentration decreased specific volume of gluten free breads. Likewise buckwheat flour added cakes; soy protein addition did not show any enhancing effect on specific volume of cakes. On the contrary, soy protein added samples had even lower specific volume than control. Guar gum was another hydrocolloid that negatively influenced the specific volume of cakes. The results of gum/protein type were in accordance with specific gravity results. For example, air incorporation to batter was the highest in whey protein added samples. The specific volumes were in the following decreasing order; whey protein, xanthan gum, control, soy protein, and guar gum.

According to three way ANOVA results (Table A.58); different flour type did not create a significant difference between specific volumes of cakes. As expected, whey protein added cakes prepared with carob flour and buckwheat flour had the highest specific volume. As mentioned before, due to high dietary fiber, globulin proteins; one of the storage protein present in buckwheat; swelling and gelling feature might provide buckwheat to have high specific volume. On the other hand, gluten like protein in carob germ flour; caroubin; might be responsible from its high specific volume. Although bonds created by caroubin were weaker than gluten did, it could form a network similar to gluten, and then could strengthen batter because of disulfide bonded high molecular weight proteins (Minarro, Albanell, Aguilar, Guamis, & Capellas, 2012; Tsatsaragkou, Gounaropoulos, & Mandala, 2014; Smith et al., 2012).

3.2.4 Hardness

Textural analysis of cakes was evaluated in terms of hardness. As can be seen from Figure 3.20, concentration of flour and gum/protein types had a significant influence on this quality parameter. Hardness results were found to be correlated with specific gravity and specific volume results. Correlation coefficient between specific volume and hardness was -0.879 (p=0.000). It meant that samples with high specific volume had the softest texture, which was a desired case for cake samples. Besides, correlation coefficient between specific gravity and hardness was 0.800 (p=0.000).

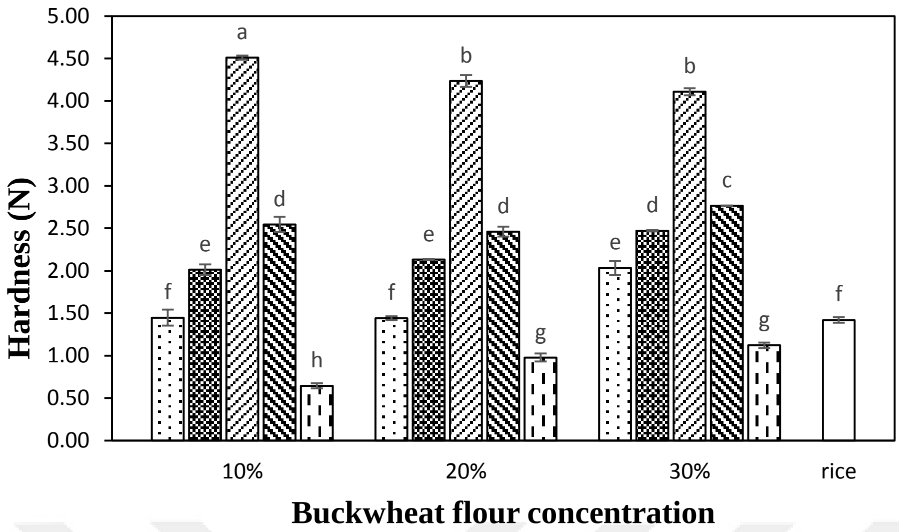

Figure 3. 20 Hardness of cakes prepared with different buckwheat flour concentration and gum/ protein type: control (▯), xanthan (▯), guar (▯), soy protein (▯), whey protein (▯), rice (▯). Bars having different letters are significantly different (p≤0.05).

When more air was incorporated into cake batter, samples had higher volume, which resulted in softer texture. The softest crumb was measured for buckwheat flour cakes with whey protein and the highest hardness was measured for buckwheat flour cakes with guar gum (Table A.63). This result was also supported by many studies. It was reported that guar gum added yellow layer cakes (Gomez et al., 2007) and rice cakes with guar gum (Turabi et al., 2008) had the hardest texture. Furthermore, addition of soy protein to formulation did not show the desired influence on texture of gluten free cakes. Similar results were obtained by a study conducted by Crockett, (2009). It was stated that disulfide linkages might reduce surface hydrophobicity and foam stability which resulted in losing of flexible film between water air interfaces. Therefore, less incorporation of air into the cake batters resulted in increasing hardness of cakes. Increasing buckwheat flour concentration from 10% to 20% did not create significant difference. However, 30% buckwheat added cakes had the highest hardness. This may be due to the fact that increasing flour content accompanied with higher fiber amount. Gularte et al., (2012) reported that increasing fiber content had an undesirable effect on hardness. This might be due to thickening cell walls of gas bubbles in crumb (Gómez, Ronda, Blanco, Caballero, & Apesteguía, 2003). For all flour content; from the softest to hardest texture was ranged as whey protein, control, xanthan gum, soy protein and guar gum added samples. Since measured quality parameters (specific gravity, porosity, and specific volume) were related to each other as mentioned above, reason of obtaining such a result for hardness was supported by reasons explained in detail in section 3.2.2 and 3.2.3.

The effect of carob bean flour concentration and gum/protein types on hardness were shown in Figure 3.21. Similar to buckwheat flour added cakes; specific volume was negatively correlated with hardness of cakes in carob bean flour containing cakes (Table A.68). Correlation coefficient between specific volume and hardness was -0.833 (p=0.000), which means that higher hardness values were recorded for samples with low specific volume. Hardness of cakes varied between 1.16 N and 5.08 N. Cakes containing 30% concentration carob bean flour and guar gum had the highest hardness value. On the other hand; similar to buckwheat flour containing cakes; 10% carob bean containing cakes with whey protein had the lowest hardness. Different from buckwheat cakes, changing carob bean flour concentration in the range of 10%-30% created a significant difference in terms of hardness. While 10% and 30% concentration led to increasing hardness, 20% carob bean flour containing cakes had the softest texture. Similar pattern; decreasing and increasing tendency with respect to increasing chestnut flour concentration; was also attained in a study conducted by Demirkesen et al. (2010). This result was associated with the fiber content. It was stated that fiber and water content had a critical importance on quality parameters of baked products. While optimum fiber amount enhanced volume and textural properties, excess amount led to less volume and unacceptable textural properties. Therefore, fiber content in 10% carob flour content might be less to enhance properties, but 30% carob might be high to get optimum hardness. In carob bean flour containing cakes; whey, xanthan, control, soy and guar samples could be sorted in terms of texture from the softest to the hardest texture respectively. In general, xanthan added cakes had similar hardness values with control of 20% and 30% carob bean flour added samples.

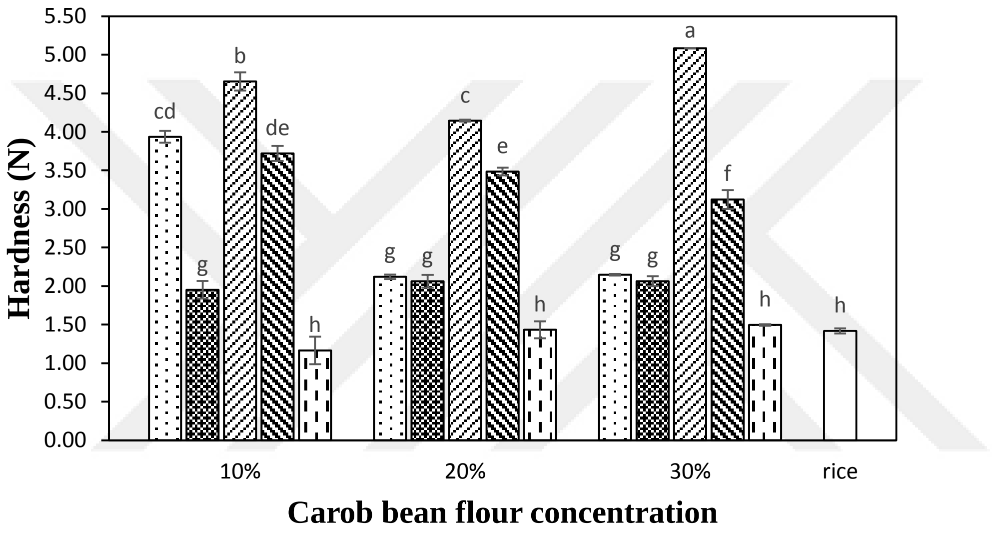

Figure 3. 21 Hardness of cakes prepared with different carob bean flour concentration and gum/ protein type: control (), xanthan (), guar (), soy protein (), whey protein (), rice (). Bars having different letters are significantly different (p≤0.05).

According to three way ANOVA results (Table A.69), cake formulation containing carob bean flour had the firmer texture than buckwheat added ones. Fiber type, protein content and type might be the reasons why cakes prepared with carob bean flour had higher hardness. Hera, Martinez, Oliete, & Gómez, (2013) investigated the effect of flour particle size on quality parameters of gluten free rice bread. It was stated that finer size flours resulted in low air retention capacity which caused more compact structure and firmer texture. Although Sauter mean diameter (volume surface mean diameter) of buckwheat flour was found as 0.160 mm, that of carob bean flour was estimated as 0.075mm. Therefore, Sauter mean diameter of particles might be another reason why carob bean added samples had higher hardness values.

3.2.5. Color

Surface color formation is an important quality parameter together with aroma for product acceptance of consumers (Zanoni, Peri, & Bruno, 1995). During baking, the physicochemical changes occurring especially on the surface of product are Maillard browning (non-enzymatic browning) and caramelization reactions. Maillard reactions take place in the presence of reducing sugar, amino acids, and nitrogen containing compounds. At the end of the reaction, melanoidin formation is observed. On the other hand, caramelization reactions occur due to direct heating of carbohydrates including sucrose at elevated temperatures. Furthermore, for some cases, both of these reactions can take place (Purlis & Salvadori, 2009). Effect of gum/protein types and buckwheat flour concentration on color change were represented in Figure 3.22. Whey protein containing cakes had always the highest ΔE^*value. The higher protein content in these cakes could have higher degree of browning reactions which resulted in higher ΔE^*value. Regardless of concentration of buckwheat in cake, whey protein promoted browning reactions and led to the highest color change. Cakes with 10% concentration buckwheat had a significantly different ΔE^* than 20% and 30% (Table A.74). Furthermore, less color formation was detected gum added cakes. Since gums prevent moisture loss (Table A.30, Table A.35), moisture accumulating on the surface might slow down the reaction rate which could result in less browning reactions.

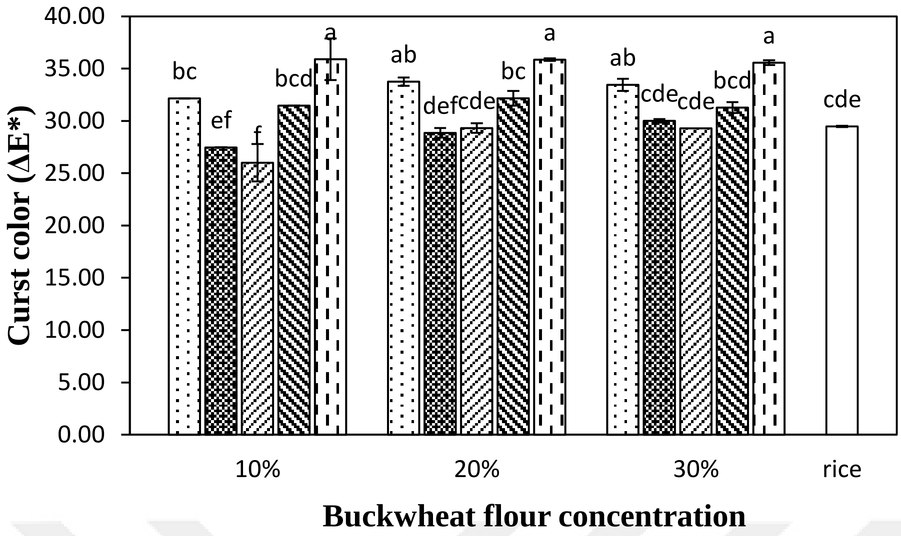

Figure 3. 22 Color of cakes prepared with different buckwheat flour concentration and gum/ protein type: control (), xanthan (), guar (), soy protein (), whey protein (), rice (). Bars having different letters are significantly different (p≤0.05).

Effects of carob bean flour concentration and gum/protein type on color change have been shown in Figure 3.23. Cake containing only rice flour had the lowest ΔE^* value as compared to cakes with carob bean flour since carob bean flour had already much darker color than rice. Whey protein added cakes were the darkest. According to ANOVA (Table A.79) results, concentration difference between cakes led the some differences. Although cakes with 20% and 30% carob bean flour had the same color change, cake with 10% concentration had lighter color. Similar to buckwheat results, gum addition resulted in less color formation.

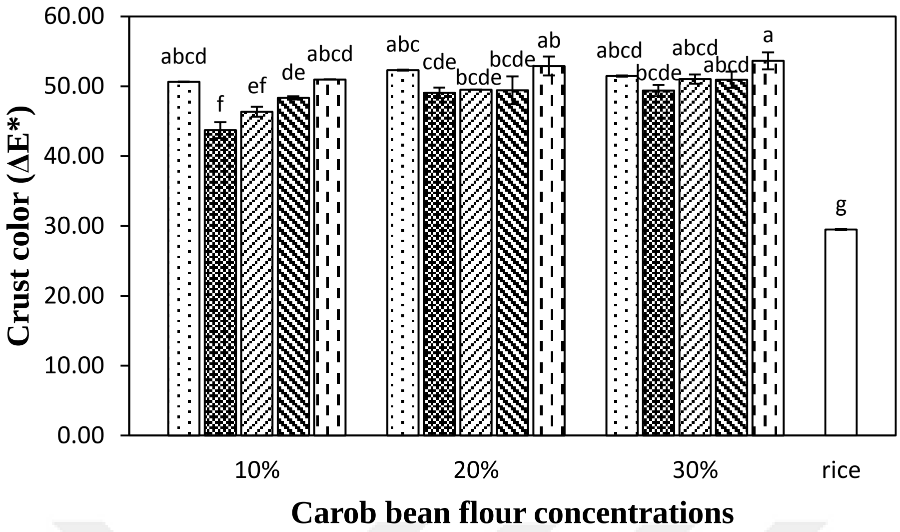

Figure 3. 23 Color of cakes prepared with different carob bean flour concentration and gum/ protein type: control (▯), xanthan (▩), guar (▨), soy protein (▧), whey protein (▯), rice (▭). Bars having different letters are significantly different (p≤0.05).

According to ANOVA (Table A.80) results, flour types significantly affected color formation since carob bean flour had a natural darker color. In addition to that, carob bean flour contains high amount of sugar, which might lead to improvement of caramelization reactions. Regardless of the flour type used, although whey protein improved color, gum addition led to lighter color formation.

3.2.6 Effect of Whey Protein and Guar Gum on Macro Structure of Cake Containing 10% Buckwheat Flour

Figure 3.24 and 3.25 represents the scanned and binarised images of cakes containing 10% buckwheat flour. As can be seen from Figure 3.26, difference in formulation of cakes created significant difference in terms of pore area fraction.

While whey added cakes reached the highest pore area fraction, guar gum containing cakes had the lowest.

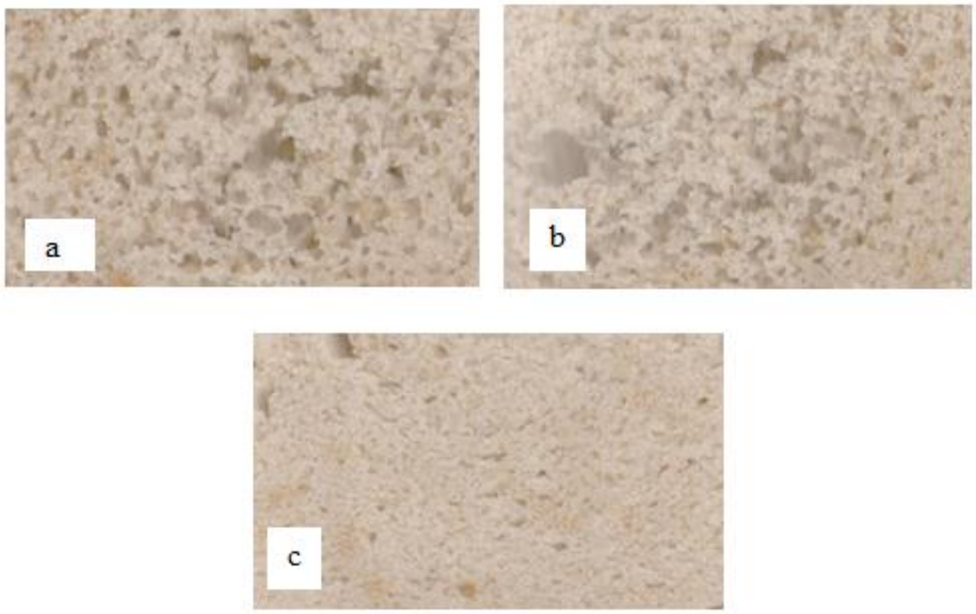

Figure 3. 24 Scanned images of cakes formulated with 10% buckwheat flour control (a), whey protein added (b), guar gum added (c)

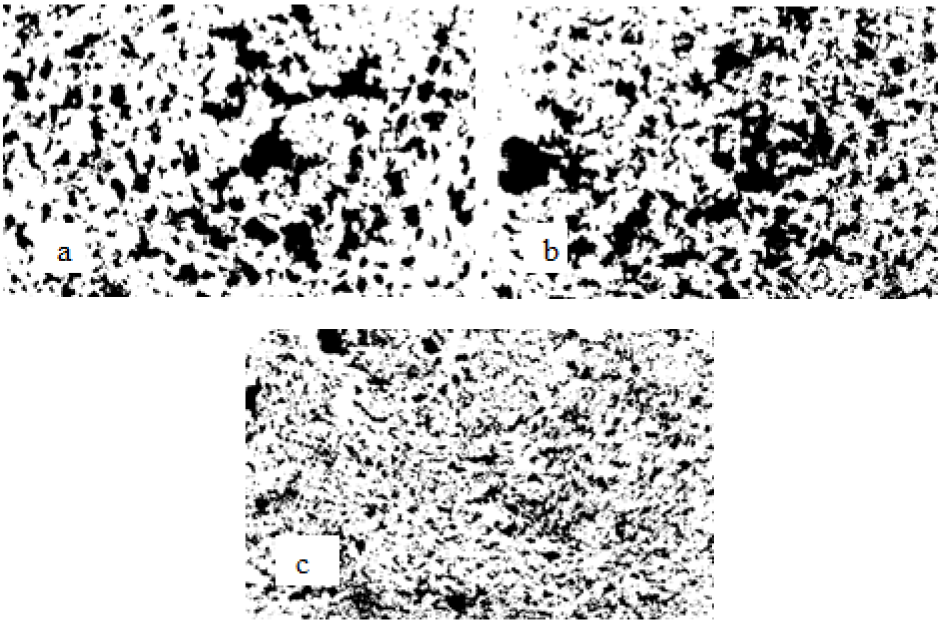

Figure 3. 25 Binarised images of cakes formulated with 10% buckwheat flour control (a), whey protein added (b), guar gum added (c)

Rheology and specific gravity results supported such a distribution of area fraction. As mentioned, whey added batter and control one had the lowest consistency index value which was due to higher air incorporation to batter (Table A.4). More air incorporation of gas into batter was an indication of more porous structure of baked cakes, which was also confirmed by specific gravity results. While lowest specific gravity was measured in whey containing batters, guar gum added ones had the highest value (Table A.14, Table A.25). Batter morphology and pore area fraction results supported each other .As can be seen from Figure 3.13, cake batter with whey protein had higher number of gas cells compared to control batter and guar gum added ones. Similarly these cakes had the highest pore area fraction (Figure 3.26). Higher pore area fraction can be interpreted as more porous structure. Cakes containing whey protein had the highest area fraction which was also correlated to porosity, specific volume and the texture results (Table A.25, Table A.47, Table A.58, and Table A.69). Due to good emulsification ability of whey protein, whey added samples always had higher quality.

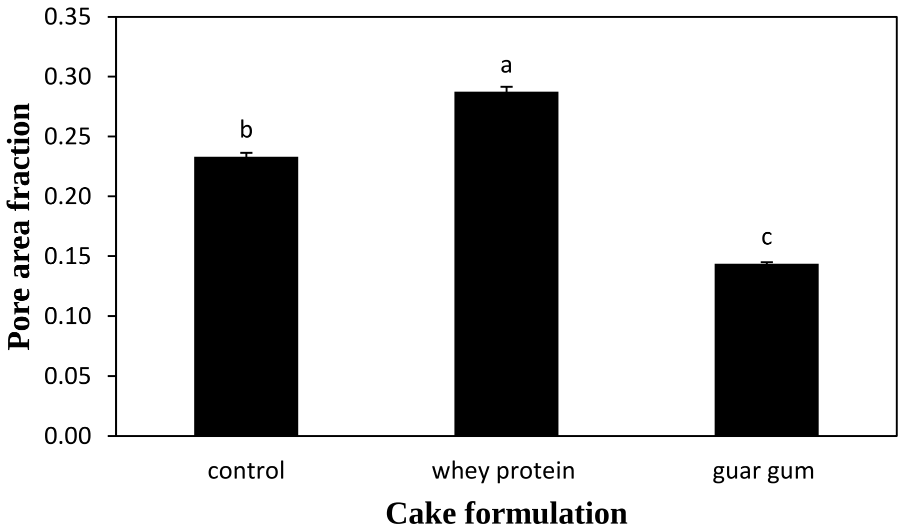

Figure 3. 26 Effect of formulation on pore area of cake with 10% buckwheat flour

In Table 3.5 pore area distribution of cakes containing 10% buckwheat flour was shown. As seen from the table, although guar gum had the highest number of pores, according to porosity results, it had the lowest porosity. It means that size of pores and area distribution might be more important for cakes to have high porosity rather than number of pores. Half of the pores that guar gum added cakes had were very small-size. Furthermore, morphological analysis of batters also supported such a result since as seen Figure 3.13, guar gum containing batters had very small sized gas bubbles with uneven distribution On the other hand, in whey protein added cakes, more uniform area distribution of cakes can be observed, which might be the reason these cakes had higher porosity than the others. Although control cake had more pore than cake with whey protein, more uniform size distribution of pores was obtained whey protein added cakes, which might be the reason of lower hardness and higher specific volume the cakes (Table A.58).

Table 3. 5 Pore area distributions of cakes containing 10% buckwheat flour prepared with different formulations

Number of Pores	Control	Whey protein	Guar gum
Range of pore area (mm^2)			
0.5-1	40	29	51
1-2	21	21	23
2-3	9	8	11
3-4	9	7	2
4-5	6	6	1
5-10	2	5	3
10-15	1	3	1
15-20	2	1	-
>20	1	2	-
Total number of pores	91	82	92

CHAPTER 4

CONCLUSION AND RECOMMENDATIONS

All cake batters showed shear thinning behavior and obeyed the Power law model. Addition of gum and increasing flour concentration in formulation had an increasing effect on consistency index and apparent viscosity. Increasing elasticity of batter and storage modulus was found to be correlated with gum addition and buckwheat or carob bean flour concentration. Addition of whey protein to cake batter decreased specific gravity with increasing air incorporation. Whey protein containing batters had more uniform gas bubble distribution and high number of pores. Correct interpretation of rheological and physical properties of cake batter can provide advantages while developing gluten free cake.

Gum addition to the formulation significantly decreased weight loss of cakes. Although whey protein enhanced the porosity of cakes, soy protein did not show the same effect. Another factor having negative influence on porosity was increasing buckwheat and carob bean flour concentration. Because of this reason, addition of flour to formulation in lower amount might be advised. It was also found that cakes containing buckwheat flour had more porous structure, higher specific volume and lower texture as compared to carob flour added cakes. Therefore, to obtain cakes with less moisture loss and high quality, buckwheat flour may be recommended.

Whey protein was the only ingredient that improved specific volume. Whey addition also helped to increase porosity. Due to lower volume and less porous structure of soy protein containing cakes, they had the highest hardness value following guar gum added ones. As a result, 10% buckwheat flour addition to cake formulation including whey protein can be recommended to celiac patients as a gluten free cakes due to its high quality and nutritional value.

For future studies, the effect of other proteins such as casein, pea protein, and egg white protein on rheology of batter and quality of cake may be investigated. Besides, impact of addition gums together with proteins to formulation can be studied. In addition to that, staling characteristics of those cakes can be analyzed. The effect of oven type on cake characteristic (microwave oven- microwave infrared combination oven) can also be studied.

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APPENDIX A

STATISTICAL ANALYSIS

Table A. 1 One way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by 10% buckwheat flour concentration with gums and proteins

```
Source            DF       SS      MS       F      P
cake batter        4  24777,1  6194,3  474,58  0,000
Error              5     65,3    13,1
Total              9  24842,3

S = 3,613   R-Sq = 99,74%   R-Sq(adj) = 99,53%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level         N    Mean  StDev  ---------+---------+---------+---------+
bck10control  2   48,34   6,25   (-*-)
bck10guar     2  121,35   1,16                        (-*-)
bck10soy      2   56,33   2,68     (-*-)
bck10whey     2   44,40   0,61  (-*-)
bck10xanthan  2  170,46   4,16                                      (-*-)
                                ---------+---------+---------+---------+
                                        70       105       140       175

Pooled StDev = 3,61


Grouping Information Using Tukey Method

cake batter   N    Mean  Grouping
bck10xanthan  2  170,46  A
bck10guar     2  121,35    B
bck10soy      2   56,33      C
bck10control  2   48,34      C
bck10whey     2   44,40      C
```

Table A. 2 One way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by 20% buckwheat flour concentrationn with gums and proteins

```
Source            DF       SS      MS       F      P
cake batter        4  32564,9  8141,2  798,19  0,000
Error              5     51,0    10,2
```

```
Total              9  32615,9

S = 3,194   R-Sq = 99,84%   R-Sq(adj) = 99,72%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level          N    Mean  StDev  -----+---------+---------+---------+----
bck20control  2   68,63   1,34   (*-)
bck20guar     2  142,52   6,12                     (-*)
bck20soy      2   73,23   2,11     (*-)
bck20whey     2   65,98   1,98   (*-)
bck20xanthan  2  211,25   1,85                                      (-*)
                                 -----+---------+---------+---------+----
                                     80        120       160       200

Pooled StDev = 3,19


Grouping Information Using Tukey Method

cake batter   N    Mean  Grouping
bck20xanthan  2  211,25  A
bck20guar     2  142,52    B
bck20soy      2   73,23      C
bck20control  2   68,63      C
bck20whey     2   65,98      C
```

Table A. 3 One way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by 30% buckwheat flour concentration with gums and proteins

```
Source        DF       SS      MS       F      P
cake batter   4  33164,1  8291,0  248,24  0,000
Error         5    167,0    33,4
Total         9  33331,1

S = 5,779   R-Sq = 99,50%   R-Sq(adj) = 99,10%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level          N    Mean  StDev  -----+---------+---------+---------+----
bck30control  2   86,17   1,61   (-*-)
bck30guar     2  174,86   7,23                   (-*-)
bck30soy      2  107,06   4,79       (-*--)
bck30whey     2   83,37   2,89   (-*-)
bck30xanthan  2  230,77   8,99                              (-*-)
                                 -----+---------+---------+---------+----
                                    100       150       200       250

Pooled StDev = 5,78


Grouping Information Using Tukey Method

cake batter       N    Mean  Grouping
bck30xanthan  2  230,77  A
bck30guar     2  174,86    B
bck30soy      2  107,06      C
bck30control  2   86,17      C D
bck30whey     2   83,37        D
```

Table A. 4 Two way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by different buckwheat flour concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for K, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type	4	89835,9	89835,9	22459,0	1189,33	0,000
conc	2	11649,2	11649,2	5824,6	308,44	0,000
Gum/ protein type*conc	8	670,2	670,2	83,8	4,44	0,006
Error	15	283,3	283,3	18,9		
Total	29	102438,5				

S = 4,34554   R-Sq = 99,72%   R-Sq(adj) = 99,47%

Unusual Observations for K

Obs	K	Fit	SE Fit	Residual	St Resid
9	237,128	230,772	3,073	6,356	2,07 R
10	224,416	230,772	3,073	-6,356	-2,07 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
xanthan	6	204,2	A
guar	6	146,2	B
soy	6	78,9	C
control	6	67,7	D
whey	6	64,6	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
30	10	136,4	A
20	10	112,3	B
10	10	88,2	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
xanthan	30	2	230,8	A
xanthan	20	2	211,2	B
guar	30	2	174,9	C
xanthan	10	2	170,5	C
guar	20	2	142,5	D
guar	10	2	121,3	E
soy	30	2	107,1	E
control	30	2	86,2	F
whey	30	2	83,4	F G

```
soy               20    2   73,2            F G H
control           20    2   68,6              G H
whey              20    2   66,0                H
soy               10    2   56,3                H I
control           10    2   48,3                  I
whey              10    2   44,4                  I
```

Table A. 5 Two way ANOVA and Tukey's Comparison Test for flow behavior index values (n) of cake batters prepared by different buckwheat flour conc (10%, 20% and 30%) with gums and proteins

```
Factor         Type   Levels  Values
cake batter    fixed       5  control; guar; soy; whey; xanthan
conc           fixed       3  10; 20; 30


Analysis of Variance for n, using Adjusted SS for Tests

Source            DF     Seq SS     Adj SS     Adj MS      F      P
cake batter        4  0,0211078  0,0211078  0,0052770  29,29  0,000
conc               2  0,0029503  0,0029503  0,0014751   8,19  0,004
cake batter*conc   8   0,0086777 0,0086777  0,0010847   6,02  0,001
Error             15  0,0027025  0,0027025  0,0001802
Total             29  0,0354384


S = 0,0134227   R-Sq = 92,37%   R-Sq(adj) = 85,26%


Unusual Observations for n

Obs         n       Fit    SE Fit   Residual  St Resid
  9  0,333000  0,359250  0,009491  -0,026250     -2,77 R
 10  0,385500  0,359250  0,009491   0,026250      2,77 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

cake batter  N  Mean  Grouping
control      6   0,4  A
whey         6   0,4  A B
soy          6   0,4  A B
guar         6   0,4    B
xanthan      6   0,3      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10     10   0,4  A
20     10   0,4  A B
30     10   0,4    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

cake batter  conc    N  Mean  Grouping
control       10     2   0,4  A
```

```
whey          10     2   0,4  A B
soy           20     2   0,4  A B
guar          20     2   0,4  A B C
soy           10     2   0,4  A B C
control       30     2   0,4  A B C D
guar          10     2   0,4  A B C D
whey          20     2   0,4    B C D
whey          30     2   0,4    B C D
control       20     2   0,4    B C D
soy           30     2   0,4    B C D E
xanthan       30     2   0,4      C D E
guar          30     2   0,4        D E
xanthan       20     2   0,3          E
xanthan       10     2   0,3          E
```

Table A. 6 One way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by 10% carob bean flour conc with gums and proteins

```
Source       DF        SS       MS        F      P
cake batter   4  29166,74  7291,68  6939,79  0,000
Error         5      5,25     1,05
Total         9  29171,99

S = 1,025   R-Sq = 99,98%   R-Sq(adj) = 99,97%

                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level        N    Mean  StDev  ---------+---------+---------+---------+
crb10control  2   40,69   1,50  (*
crb10guar     2  131,68   0,49                          (*
crb10soy      2   55,82   0,80      (*
crb10whey     2   42,27   0,85   *)
crb10xanthan  2  173,52   1,18                                      (*
                                ---------+---------+---------+---------+
                                        70       105       140       175

Pooled StDev = 1,03


Grouping Information Using Tukey Method

cake batter   N    Mean  Grouping
crb10xanthan  2  173,52  A
crb10guar     2  131,68    B
crb10soy      2   55,82      C
crb10whey     2   42,27        D
crb10control  2   40,69        D
```

Table A. 7 One way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by 20% carob bean flour conc with gums and proteins

```
Source       DF       SS      MS       F      P
cake batter   4  32700,2  8175,0  302,86  0,000
Error         5    135,0    27,0
Total         9  32835,1

S = 5,195   R-Sq = 99,59%   R-Sq(adj) = 99,26%


                                Individual 95% CIs For Mean Based on
```

```
                                Pooled StDev
Level          N    Mean  StDev  -+---------+---------+---------+--------
crb20control   2   46,09   5,52  (--*-)
crb20guar      2  144,35   5,37                          (-*-)
crb20soy       2   62,65   0,14      (--*-)
crb20whey      2   48,46   1,99   (-*-)
crb20xanthan   2  186,34   8,47                                    (--*)
                                 -+---------+---------+---------+--------
                                 40        80       120       160

Pooled StDev = 5,20


Grouping Information Using Tukey Method

cake batter    N    Mean  Grouping
crb20xanthan   2  186,34  A
crb20guar      2  144,35    B
crb20soy       2   62,65      C
crb20whey      2   48,46      C
crb20control   2   46,09      C
```

Table A. 8 One way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by 30% carob bean flour conc with gums and proteins

```
Source        DF       SS      MS       F      P
cake batter    4  20776,0  5194,0  383,05  0,000
Error          5     67,8    13,6
Total          9  20843,8

S = 3,682   R-Sq = 99,67%   R-Sq(adj) = 99,41%


                                Individual 95% CIs For Mean Based on
                                Pooled StDev
Level          N    Mean  StDev  --+---------+---------+---------+-------
crb30control   2   59,51   1,04  (-*-)
crb30guar      2  155,56   6,33                                (-*-)
crb30soy       2   76,12   1,99       (-*--)
crb30whey      2   59,86   4,75  (-*-)
crb30xanthan   2  159,17   0,29                                 (-*-)
                                 --+---------+---------+---------+-------
                                  60        90       120       150

Pooled StDev = 3,68


Grouping Information Using Tukey Method

cake batter    N    Mean  Grouping
crb30xanthan   2  159,17  A
crb30guar      2  155,56  A
crb30soy       2   76,12    B
crb30whey      2   59,86      C
crb30control   2   59,51      C
```

Table A. 9 Two way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

```
Factor       Type   Levels  Values
conc         fixed       3  10; 20; 30
cake batter  fixed       5  crbcontrol; crbguar; crbsoy; crbwhey; crbxanthan


Analysis of Variance for K, using Adjusted SS for Tests

Source                   DF   Seq SS   Adj SS   Adj MS        F      P
conc                      2    908,6    908,6    454,3    32,76  0,000
gum/ protein type         4  81120,9  81120,9  20280,2  1462,41  0,000
conc* gum/ protein type   8   1522,1   1522,1    190,3    13,72  0,000
Error                    15    208,0    208,0     13,9
Total                    29  83759,6


S = 3,72393   R-Sq = 99,75%   R-Sq(adj) = 99,52%


Unusual Observations for K

Obs        K      Fit  SE Fit  Residual  St Resid
 13  180,350  186,339   2,633    -5,989     -2,27 R
 14  192,328  186,339   2,633     5,989      2,27 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/ protein type   N   Mean  Grouping
crbxanthan          6  173,0  A
crbguar             6  143,9    B
crbsoy              6   64,9      C
crbwhey             6   50,2        D
crbcontrol          6   48,8        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N   Mean  Grouping
30    10  102,0  A
20    10   97,6    B
10    10   88,8      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc  gum/ protein type   N   Mean  Grouping
20    crbxanthan          2  186,3  A
10    crbxanthan          2  173,5  A B
30    crbxanthan          2  159,2    B C
30    crbguar             2  155,6      C
20    crbguar             2  144,4      C D
10    crbguar             2  131,7        D
30    crbsoy              2   76,1          E
20    crbsoy              2   62,6          E F
30    crbwhey             2   59,9            F G
30    crbcontrol          2   59,5            F G
10    crbsoy              2   55,8            F G H
20    crbwhey             2   48,5            F G H I
20    crbcontrol          2   46,1              G H I
10    crbwhey             2   42,3                H I
```

```
10    crbcontrol         2   40,7                  I
```

Table A. 10 Two way ANOVA and Tukey's Comparison Test for flow behavior index values (n) of cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

```
Factor       Type   Levels  Values
conc         fixed  3  10; 20; 30
cake batter  fixed  5  crbcontrol; crbguar; crbsoy; crbwhey; crbxanthan


Analysis of Variance for n, using Adjusted SS for Tests

Source             DF     Seq SS     Adj SS     Adj MS      F      P
conc                2  0,0083838  0,0083838  0,0041919  15,53  0,000
cake batter         4  0,0373800  0,0373800  0,0093450  34,63  0,000
conc*cake batter    8  0,0107564  0,0107564  0,0013446   4,98  0,004
Error              15  0,0040479  0,0040479  0,0002699
Total              29  0,0605681


S = 0,0164274   R-Sq = 93,32%   R-Sq(adj) = 87,08%


Unusual Observations for n

Obs         n       Fit    SE Fit   Residual  St Resid
 11  0,429700  0,397500  0,011616   0,032200      2,77 R
 12  0,365300  0,397500  0,011616  -0,032200     -2,77 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

cake batter  N  Mean  Grouping
crbcontrol   6   0,4  A
crbwhey      6   0,4  A B
crbsoy       6   0,4    B
crbguar      6   0,3      C
crbxanthan   6   0,3      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10    10   0,4  A
20    10   0,4    B
30    10   0,3    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc  cake batter  N  Mean  Grouping
10    crbcontrol   2   0,4  A
10    crbwhey      2   0,4  A B
20    crbwhey      2   0,4  A B
10    crbsoy       2   0,4  A B C
20    crbcontrol   2   0,4  A B C D
30    crbcontrol   2   0,4  A B C D E
```

```
30    crbsoy       2   0,4    B C D E
20    crbsoy       2   0,4    B C D E
10    crbguar      2   0,3      C D E F
20    crbguar      2   0,3      C D E F
30    crbwhey      2   0,3      C D E F
30    crbxanthan   2   0,3        D E F
30    crbguar      2   0,3          E F
10    crbxanthan   2   0,3          E F
20    crbxanthan   2   0,3            F
```

Table A. 11 Three way ANOVA and Tukey's Comparison Test for consistency index (K) values of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

```
Factor            Type   Levels  Values
gum/protein type  fixed       5  control; guar; soy; whey; xanthan
flour             fixed       2  bck; crb
conc              fixed       3  10; 20; 30

Analysis of Variance for K, using Adjusted SS for Tests

Source                    DF    Seq SS    Adj SS   Adj MS        F      P
gum/protein type           4  169666,8  169666,8  42416,7  2590,22  0,000
flour                      1    3924,1    3924,1   3924,1   239,63  0,000
conc                       2    9476,5    9476,5   4738,2   289,35  0,000
gum/protein type*flour     4    1290,0    1290,0    322,5    19,69  0,000
gum/protein type*conc      8    1038,9    1038,9    129,9     7,93  0,000
flour*conc                 2    3081,3    3081,3   1540,7    94,08  0,000
gum/proteintype*flour*conc 8 1153,4    1153,4    144,2     8,80  0,000
Error                     30    491,3     491,3     16,4
Total                     59  190122,2


S = 4,04669   R-Sq = 99,74%   R-Sq(adj) = 99,49%


Unusual Observations for K

Obs        K      Fit  SE Fit  Residual  St Resid
 13  180,350  186,339   2,861    -5,989     -2,09 R
 14  192,328  186,339   2,861     5,989      2,09 R
 53  237,128  230,772   2,861     6,356      2,22 R
 54  224,416  230,772   2,861    -6,356     -2,22 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type   N   Mean  Grouping
xanthan           12  188,6  A
guar              12  145,1    B
soy               12   71,9      C
control           12   58,2        D
whey              12   57,4        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

flour   N   Mean  Grouping
bck    30  112,3  A
crb    30   96,1    B
```

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
30	20	119,2	A
20	20	104,9	B
10	20	88,5	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	flour	N	Mean	Grouping
xanthan	bck	6	204,2	A
xanthan	crb	6	173,0	B
guar	bck	6	146,2	C
guar	crb	6	143,9	C
soy	bck	6	78,9	D
control	bck	6	67,7	E
soy	crb	6	64,9	E
whey	bck	6	64,6	E
whey	crb	6	50,2	F
control	crb	6	48,8	F

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	conc	N	Mean	Grouping
xanthan	20	4	198,8	A
xanthan	30	4	195,0	A
xanthan	10	4	172,0	B
guar	30	4	165,2	B
guar	20	4	143,4	C
guar	10	4	126,5	D
soy	30	4	91,6	E
control	30	4	72,8	F
whey	30	4	71,6	F
soy	20	4	67,9	F
control	20	4	57,4	G
whey	20	4	57,2	G
soy	10	4	56,1	G
control	10	4	44,5	H
whey	10	4	43,3	H

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	conc	N	Mean	Grouping
bck	30	10	136,4	A
bck	20	10	112,3	B
crb	30	10	102,0	C
crb	20	10	97,6	C
crb	10	10	88,8	D
bck	10	10	88,2	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	flour	conc	N	Mean	Grouping
xanthan	bck	30	2	230,8	A
xanthan	bck	20	2	211,2	B
xanthan	crb	20	2	186,3	C
guar	bck	30	2	174,9	C D
xanthan	crb	10	2	173,5	C D
xanthan	bck	10	2	170,5	C D E
xanthan	crb	30	2	159,2	D E F
guar	crb	30	2	155,6	E F
guar	crb	20	2	144,4	F G
guar	bck	20	2	142,5	F G
guar	crb	10	2	131,7	G H
guar	bck	10	2	121,3	H I
soy	bck	30	2	107,1	I
control	bck	30	2	86,2	J
whey	bck	30	2	83,4	J K
soy	crb	30	2	76,1	J K L
soy	bck	20	2	73,2	J K L
control	bck	20	2	68,6	K L M
whey	bck	20	2	66,0	L M
soy	crb	20	2	62,6	L M N
whey	crb	30	2	59,9	L M N O
control	crb	30	2	59,5	L M N O
soy	bck	10	2	56,3	M N O P
soy	crb	10	2	55,8	M N O P
whey	crb	20	2	48,5	N O P
control	bck	10	2	48,3	N O P
control	crb	20	2	46,1	N O P
whey	bck	10	2	44,4	O P
whey	crb	10	2	42,3	P
control	crb	10	2	40,7	P

Table A. 12 Two way ANOVA and Tukey's Comparison Test for tan δ of cake batters prepared by different buckwheat flour concns (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
gum/protein types	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for tan, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
gum/protein types	4	0,0681649	0,0681649	0,0170412	19,74	0,000
conc	2	0,0026558	0,0026558	0,0013279	1,54	0,247
gum/protein types*conc	8	0,0088845	0,0088845	0,0011106	1,29	0,321
Error	15	0,0129500	0,0129500	0,0008633		
Total	29	0,0926552				

S = 0,0293825   R-Sq = 86,02%   R-Sq(adj) = 72,98%

Unusual Observations for tan

Obs	tan	Fit	SE Fit	Residual	St Resid
19	0,603000	0,558500	0,020777	0,044500	2,14 R
20	0,514000	0,558500	0,020777	-0,044500	-2,14 R
21	0,425000	0,469500	0,020777	-0,044500	-2,14 R
22	0,514000	0,469500	0,020777	0,044500	2,14 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein types	N	Mean	Grouping
whey	6	0,5	A
soy	6	0,5	A B
control	6	0,4	B C
xanthan	6	0,4	C D
guar	6	0,4	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
20	10	0,5	A
30	10	0,4	A
10	10	0,4	A

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein types	conc	N	Mean	Grouping
whey	20	2	0,6	A
whey	30	2	0,5	A B
soy	20	2	0,5	A B C
whey	10	2	0,5	A B C
control	30	2	0,5	A B C D
soy	30	2	0,5	A B C D
soy	10	2	0,5	A B C D
xanthan	20	2	0,4	B C D
control	20	2	0,4	B C D
control	10	2	0,4	B C D
xanthan	30	2	0,4	B C D
xanthan	10	2	0,4	B C D
guar	10	2	0,4	B C D
guar	20	2	0,4	C D
guar	30	2	0,4	D

Table A. 13 Two way ANOVA and Tukey's Comparison Test for tan δ of cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
gum/protein types	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for tan, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
gum/protein types	4	0,114909	0,114909	0,028727	77,66	0,000
conc	2	0,024568	0,024568	0,012284	33,21	0,000
gum/protein types*conc	8	0,021430	0,021430	0,002679	7,24	0,001
Error	15	0,005549	0,005549	0,000370		
Total	29	0,166455				

```
S = 0,0192330   R-Sq = 96,67%   R-Sq(adj) = 93,56%


Unusual Observations for tan

Obs       tan       Fit    SE Fit   Residual  St Resid
 21  0,469000  0,502500  0,013600  -0,033500     -2,46 R
 22  0,536000  0,502500  0,013600   0,033500      2,46 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein types   N  Mean  Grouping
whey                6   0,5  A
control               6   0,5  A
soy                   6   0,5    B
xanthan               6   0,4      C
guar                  6   0,4        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10    10   0,5  A
20    10   0,5    B
30    10   0,4      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein types  conc   N  Mean  Grouping
whey               10     2   0,6  A
control            20     2   0,6  A B
soy                10     2   0,5  A B C
whey               30     2   0,5    B C D
control            30     2   0,5    B C D
whey                 20     2   0,5    B C D
control            10     2   0,5    B C D E
soy                20     2   0,5      C D E F
xanthan            10     2   0,4        D E F G
xanthan            20     2   0,4          E F G
guar               10     2   0,4            F G H
soy                30     2   0,4              G H
xanthan            30     2   0,4              G H
guar               20     2   0,4              G H
guar               30     2   0,3                H
```

Table A. 14 Three way ANOVA and Tukey's Comparison Test for tan δ values of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

```
Factor              Type   Levels  Values
Gum/protein type    fixed       5  control; guar; soy; whey; xanthan
flour               fixed       2  bck; crb
conc                fixed       3  10; 20; 30
```

Analysis of Variance for tan, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/protein type	4	0,1668301	0,1668301	0,0417075	67,64	0,000
flour	1	0,0048133	0,0048133	0,0048133	7,81	0,009
conc	2	0,0115769	0,0115769	0,0057885	9,39	0,001
Gum/protein type *flou	4	0,0162438	0,0162438	0,0040610	6,59	0,001
Gum/protein type *conc	8	0,0117910	0,0117910	0,0014739	2,39	0,040
flour*conc	2	0,0156471	0,0156471	0,0078235	12,69	0,000
Gumproteintype*flour*conc	8	0,0185231	0,0185231	0,0023154	3,75	0,004
Error	30	0,0184986	0,0184986	0,0006166		
Total	59	0,2639239				

S = 0,0248318   R-Sq = 92,99%   R-Sq(adj) = 86,22%

Unusual Observations for tan

Obs	tan	Fit	SE Fit	Residual	St Resid
9	0,534000	0,493000	0,017559	0,041000	2,34 R
10	0,452000	0,493000	0,017559	-0,041000	-2,34 R
19	0,603000	0,558500	0,017559	0,044500	2,53 R
20	0,514000	0,558500	0,017559	-0,044500	-2,53 R
21	0,425000	0,469500	0,017559	-0,044500	-2,53 R
22	0,514000	0,469500	0,017559	0,044500	2,53 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type	N	Mean	Grouping
whey	12	0,5	A
control	12	0,5	B
soy	12	0,5	B
xanthan	12	0,4	C
guar	12	0,4	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	N	Mean	Grouping
crb	30	0,5	A
bck	30	0,4	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	20	0,5	A
20	20	0,5	A
30	20	0,4	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type	flour	N	Mean	Grouping
whey	crb	6	0,5	A

whey	bck	6	0,5	A B
control	crb	6	0,5	A B
soy	bck	6	0,5	B C
soy	crb	6	0,5	C
control	bck	6	0,4	C D
xanthan	bck	6	0,4	D E
xanthan	crb	6	0,4	D E
guar	bck	6	0,4	E
guar	crb	6	0,4	E

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	conc	N	Mean	Grouping
whey	10	4	0,5	A
whey	20	4	0,5	A B
whey	30	4	0,5	A B C
soy	10	4	0,5	A B C
control	20	4	0,5	A B C
control	30	4	0,5	A B C D
soy	20	4	0,5	B C D
control	10	4	0,5	C D E
soy	30	4	0,4	D E F
xanthan	10	4	0,4	D E F
xanthan	20	4	0,4	D E F
guar	10	4	0,4	E F G
xanthan	30	4	0,4	E F G
guar	20	4	0,4	F G
guar	30	4	0,3	G

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	conc	N	Mean	Grouping
crb	10	10	0,5	A
crb	20	10	0,5	A B
bck	20	10	0,5	B C
bck	30	10	0,4	B C
bck	10	10	0,4	B C
crb	30	10	0,4	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	flour	conc	N	Mean	Grouping
whey	crb	10	2	0,6	A
control	crb	20	2	0,6	A B
whey	bck	20	2	0,6	A B
soy	crb	10	2	0,5	A B C
whey	crb	30	2	0,5	A B C D
whey	bck	30	2	0,5	A B C D E
control	crb	30	2	0,5	A B C D E
whey	crb	20	2	0,5	A B C D E
soy	bck	20	2	0,5	B C D E F
whey	bck	10	2	0,5	B C D E F G
control	crb	10	2	0,5	B C D E F G
control	bck	30	2	0,5	B C D E F G H
soy	crb	20	2	0,5	B C D E F G H
soy	bck	30	2	0,5	B C D E F G H I
soy	bck	10	2	0,5	C D E F G H I

```
xanthan        crb   10  2   0,4      C D E F G H I J
xanthan       bck   20  2   0,4        D E F G H I J
control        bck   20  2   0,4        D E F G H I J
control        bck   10  2   0,4        D E F G H I J
xanthan        crb   20  2   0,4        D E F G H I J
xanthan        bck   30  2   0,4          E F G H I J
guar           crb   10  2   0,4          E F G H I J
xanthan        bck   10  2   0,4          E F G H I J
guar           bck   10  2   0,4            F G H I J
soy            crb   30  2   0,4              G H I J
guar           bck    20  2   0,4                H I J
xanthan        crb    30  2   0,4                H I J
guar           crb    20  2   0,4                H I J
guar            bck    30  2   0,4                  I J
guar            crb    30  2   0,3                    J
```

Table A. 15 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by 10% buckwheat flour conc and with gums and proteins

```
Source         DF         SS          MS       F      P
cake batter    4  0,0074346  0,0018587  77,75  0,000
Error          5  0,0001195  0,0000239
Total          9  0,0075541

S = 0,004889   R-Sq = 98,42%   R-Sq(adj) = 97,15%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N      Mean    StDev  --+---------+---------+---------+-------
bck.10.control   2  0,94938  0,00438         (---*--)
bck.10.guar      2  1,00723  0,00146                                  (---*--)
bck.10.soy       2  0,97211  0,00146                     (---*--)
bck.10.whey      2  0,92872  0,00438   (--*---)
bck.10.xanthan   2  0,94421  0,00877         (---*--)
                                        --+---------+---------+---------+-------
                                        0,925     0,950     0,975     1,000

Pooled StDev = 0,00489


Grouping Information Using Tukey Method

cake batter      N     Mean  Grouping
bck.10.guar      2  1,00723  A
bck.10.soy       2  0,97211    B
bck.10.control   2  0,94938      C
bck.10.xanthan   2  0,94421      C D
bck.10.whey      2  0,92872        D
```

Table A. 16 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by 20% buckwheat flour conc and with gums and proteins

```
Source         DF        SS         MS      F      P
cake batter    4  0,010277  0,002569  17,60  0,004
Error          5  0,000730  0,000146
Total          9  0,011007
```

```
S = 0,01208   R-Sq = 93,37%   R-Sq(adj) = 88,06%


Level             N    Mean   StDev
bck.20.control    2  0,9669  0,0058
bck.20.guar       2  1,0589  0,0015
bck.20.soy        2  0,9990  0,0015
bck.20.whey       2  0,9773  0,0000
bck.20.xanthan    2  0,9917  0,0263

                  Individual 95% CIs For Mean Based on Pooled StDev
Level               +---------+---------+---------+---------
bck.20.control      (-----*------)
bck.20.guar                                (------*-----)
bck.20.soy                   (-----*------)
bck.20.whey            (-----*-----)
bck.20.xanthan             (-----*------)
                    +---------+---------+---------+---------
                  0,945     0,980     1,015     1,050

Pooled StDev = 0,0121


Grouping Information Using Tukey Method

Cake batter       N     Mean  Grouping
bck.20.guar       2  1,05888  A
bck.20.soy        2  0,99897    B
bck.20.xanthan    2  0,99174    B
bck.20.whey       2  0,97727    B
bck.20.control    2  0,96694    B
```

Table A. 17 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by 30% buckwheat conc and with gums and proteins

```
Source       DF        SS        MS      F      P
cake batter   4  0,012570  0,003143  25,04  0,002
Error         5  0,000628  0,000126
Total         9  0,013198

S = 0,01120   R-Sq = 95,25%   R-Sq(adj) = 91,44%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level             N    Mean   StDev  ---+---------+---------+---------+------
bck.30.control    2  0,9876  0,0029       (----*----)
bck.30.guar       2  1,0713  0,0073                            (----*----)
bck.30.soy        2  1,0227  0,0000              (----*----)
bck.30.whey       2  0,9680  0,0044  (----*----)
bck.30.xanthan    2  1,0248  0,0234              (----*----)
                                    ---+---------+---------+---------+------
                                     0,960     1,000     1,040     1,080

Pooled StDev = 0,0112


Grouping Information Using Tukey Method

cake batter       N     Mean  Grouping
bck.30.guar       2  1,07128  A
```

bck.30.xanthan	2	1,02479	B
bck.30.soy	2	1,02273	B
bck.30.control	2	0,98760	B C
bck.30.whey	2	0,96798	C

Table A. 18 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by buckwheat and rice flour

Source	DF	SS	MS	F	P
cake batter	15	0,0505211	0,0033681	36,49	0,000
Error	16	0,0014770	0,0000923		
Total	31	0,0519981			

S = 0,009608   R-Sq = 97,16%   R-Sq(adj) = 94,50%

```
                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N     Mean    StDev  -------+---------+---------+---------+--
bck.10.control   2  0,94938  0,00438      (--*--)
bck.10.guar      2  1,00723  0,00146                  (-*--)
bck.10.soy       2  0,97211  0,00146           (-*--)
bck.10.whey      2  0,92872  0,00438  (--*--)
bck.10.xanthan   2  0,94421  0,00877     (--*--)
bck.20.control   2  0,96694  0,00584          (-*--)
bck.20.guar      2  1,05888  0,00146                            (--*--)
bck.20.soy       2  0,99897  0,00146                (--*--)
bck.20.whey      2  0,97727  0,00000            (-*--)
bck.20.xanthan   2  0,99174  0,02630              (--*--)
bck.30.control   2  0,98760  0,00292              (--*-)
bck.30.guar      2  1,07128  0,00730                              (--*--)
bck.30.soy       2  1,02273  0,00000                     (--*-)
bck.30.whey      2  0,96798  0,00438          (--*-)
bck.30.xanthan   2  1,02479  0,02338                     (--*--)
rice             2  0,94215  0,00000     (-*--)
                                      -------+---------+---------+---------+--
                                           0,950     1,000     1,050     1,100
```

Pooled StDev = 0,00961

Grouping Information Using Tukey Method

cake batter	N	Mean	Grouping
bck.30.guar	2	1,07128	A
bck.20.guar	2	1,05888	A B
bck.30.xanthan	2	1,02479	B C
bck.30.soy	2	1,02273	B C
bck.10.guar	2	1,00723	C D
bck.20.soy	2	0,99897	C D E
bck.20.xanthan	2	0,99174	C D E
bck.30.control	2	0,98760	C D E F
bck.20.whey	2	0,97727	D E F G
bck.10.soy	2	0,97211	D E F G
bck.30.whey	2	0,96798	E F G
bck.20.control	2	0,96694	E F G H
bck.10.control	2	0,94938	F G H
bck.10.xanthan	2	0,94421	G H
rice	2	0,94215	G H
bck.10.whey	2	0,92872	H

Table A. 19 Two way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by different buckwheat flour concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/proteintype	fixed	5	bckcontrol;bckguar;bcksoy;bckwhey;bckxanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for sg, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type	4	0,0281222	0,0281222	0,0070306	71,40	0,000
conc	2	0,0157059	0,0157059	0,0078529	79,75	0,000
Gum/proteintype*conc	8	0,0021592	0,0021592	0,0002699	2,74	0,044
Error	15	0,0014770	0,0014770	0,0000985		
Total	29	0,0474643				

S = 0,00992309   R-Sq = 96,89%   R-Sq(adj) = 93,98%

Unusual Observations for sg

Obs	sg	Fit	SE Fit	Residual	St Resid	
13	0,97314	0,99174	0,00702	-0,01860	-2,65	R
14	1,01033	0,99174	0,00702	0,01860	2,65	R
23	1,00826	1,02479	0,00702	-0,01653	-2,36	R
24	1,04132	1,02479	0,00702	0,01653	2,36	R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
30	10	1,0	A
20	10	1,0	B
10	10	1,0	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
bckguar	6	1,0	A
bcksoy	6	1,0	B
bckxanthan	6	1,0	B
bckcontrol	6	1,0	C
bckwhey	6	1,0	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
bckguar	30	2	1,1	A
bckguar	20	2	1,1	A B
bckxanthan	30	2	1,0	B C
bcksoy	30	2	1,0	B C
bckguar	10	2	1,0	C D
bcksoy	20	2	1,0	C D E

```
bckxanthan        20     2   1,0      C D E
bckcontrol        30     2   1,0      C D E F
bckwhey           20     2   1,0        D E F G
bcksoy            10     2   1,0        D E F G
bckwhey           30     2   1,0        D E F G H
bckcontrol        20     2   1,0          E F G H
bckcontrol        10     2   0,9            F G H
bckxanthan        10     2   0,9              G H
bckwhey           10     2   0,9                H
```

Table A. 20 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by 10% carob bean conc and with gums and proteins

```
Source       DF         SS         MS      F      P
cake batter   4  0,0116394  0,0029099  90,89  0,000
Error         5  0,0001601  0,0000320
Total         9  0,0117995

S = 0,005658   R-Sq = 98,64%   R-Sq(adj) = 97,56%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N     Mean    StDev -+---------+---------+---------+--------
crb.10.control   2  0,94525  0,00438     (--*---)
crb.10.guar      2  1,02996  0,00730                                    (--*---)
crb.10.soy       2  0,94835  0,00292      (--*---)
crb.10.whey      2  0,94938  0,00146      (--*---)
crb.10.xanthan   2  0,93802  0,00877  (---*--)
                                      -+---------+---------+---------+--------
                                     0,930     0,960     0,990     1,020

Pooled StDev = 0,00566


Grouping Information Using Tukey Method

cake batter       N     Mean  Grouping
crb.10.guar       2  1,02996  A
crb.10.whey       2  0,94938    B
crb.10.soy        2  0,94835    B
crb.10.control    2  0,94525    B
crb.10.xanthan    2  0,93802    B
```

Table A. 21 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by 20% carob bean conc and with gums and proteins

```
Source       DF         SS         MS       F      P
cake batter   4  0,0151860  0,0037965  404,25  0,000
Error         5  0,0000470  0,0000094
Total         9  0,0152329

S = 0,003065   R-Sq = 99,69%   R-Sq(adj) = 99,45%
```

```
Level             N     Mean    StDev
crb.20.control    2  0,96591  0,00146
crb.20.guar       2  1,03926  0,00000
crb.20.soy        2  1,01136  0,00146
crb.20.whey       2  0,94628  0,00292
crb.20.xanthan    2  0,93802  0,00584

                  Individual 95% CIs For Mean Based on Pooled StDev
Level             ---------+---------+---------+---------+
crb.20.control             (-*-)
crb.20.guar                                          (*-)
crb.20.soy                                 (-*-)
crb.20.whey          (*-)
crb.20.xanthan    (-*-)
                  ---------+---------+---------+---------+
                         0,960     0,990     1,020     1,050

Pooled StDev = 0,00306


Grouping Information Using Tukey Method

cake batter       N     Mean  Grouping
crb.20.guar       2  1,03926  A
crb.20.soy        2  1,01136    B
crb.20.control    2  0,96591      C
crb.20.whey       2  0,94628        D
crb.20.xanthan    2  0,93802        D
```

Table A. 22 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by 30% carob bean conc and with gums and proteins

```
Source        DF         SS         MS      F      P
cake batter    4  0,0203683  0,0050921  70,17  0,000
Error          5  0,0003629  0,0000726
Total          9  0,0207312

S = 0,008519   R-Sq = 98,25%   R-Sq(adj) = 96,85%


                                      Individual 95% CIs For Mean Based on
                                      Pooled StDev
Level             N     Mean    StDev  -------+---------+---------+---------+--
crb.30.control    2  1,03512  0,00000                       (---*---)
crb.30.guar       2  1,07541  0,00730                                 (---*---)
crb.30.soy        2  1,03099  0,00000                      (---*---)
crb.30.whey       2  0,94938  0,00146  (---*---)
crb.30.xanthan    2  0,97521  0,01753         (---*---)
                                      -------+---------+---------+---------+--
                                          0,960     1,000     1,040     1,080

Pooled StDev = 0,00852


Grouping Information Using Tukey Method

cake batter       N     Mean  Grouping
crb.30.guar       2  1,07541  A
crb.30.control    2  1,03512    B
crb.30.soy        2  1,03099    B
crb.30.xanthan    2  0,97521      C
crb.30.whey       2  0,94938      C
```

Table A. 23 One way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by carob bean and rice flour

```
Source        DF         SS         MS       F      P
cake batter   15  0,0640687  0,0042712  119,92  0,000
Error         16  0,0005699  0,0000356
Total         31  0,0646386

S = 0,005968   R-Sq = 99,12%   R-Sq(adj) = 98,29%


                                      Individual 95% CIs For Mean Based on
                                      Pooled StDev
Level             N     Mean    StDev  --------+---------+---------+---------+-
crb.10.control    2  0,94525  0,00438    (-*--)
crb.10.guar       2  1,02996  0,00730                         (-*--)
crb.10.soy        2  0,94835  0,00292     (-*-)
crb.10.whey       2  0,94938  0,00146     (-*--)
crb.10.xanthan    2  0,93802  0,00877  (--*-)
crb.20.control    2  0,96591  0,00146        (-*--)
crb.20.guar       2  1,03926  0,00000                            (-*-)
crb.20.soy        2  1,01136  0,00146                     (-*-)
crb.20.whey       2  0,94628  0,00292    (--*-)
crb.20.xanthan    2  0,93802  0,00584  (--*-)
crb.30.control    2  1,03512  0,00000                           (-*-)
crb.30.guar       2  1,07541  0,00730                                      (-*-)
crb.30.soy        2  1,03099  0,00000                          (-*-)
crb.30.whey       2  0,94938  0,00146     (-*--)
crb.30.xanthan    2  0,97521  0,01753           (-*-)
rice              2  0,94215  0,00000   (--*-)
                                       --------+---------+---------+---------+-
                                            0,960     1,000     1,040     1,080

Pooled StDev = 0,00597


Grouping Information Using Tukey Method

cake batter       N     Mean  Grouping
crb.30.guar       2  1,07541  A
crb.20.guar       2  1,03926    B
crb.30.control    2  1,03512    B C
crb.30.soy        2  1,03099    B C
crb.10.guar       2  1,02996    B C
crb.20.soy        2  1,01136      C
crb.30.xanthan    2  0,97521        D
crb.20.control    2  0,96591        D E
crb.30.whey       2  0,94938          E F
crb.10.whey       2  0,94938          E F
crb.10.soy        2  0,94835          E F
crb.20.whey       2  0,94628          E F
crb.10.control    2  0,94525          E F
rice              2  0,94215          E F
crb.20.xanthan    2  0,93802            F
crb.10.xanthan    2  0,93802            F
```

Table A. 24 Two way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by different carob bean concs (10%, 20% and 30%) with gums and proteins

```
Factor             Type   Levels  Values
```

```
Gum/proteintype fixed      5  crbcontrol;crbguar; crbsoy; crbwhey; crbxanthan
conc            fixed      3  10; 20; 30


Analysis of Variance for sg, using Adjusted SS for Tests

Source                  DF     Seq SS     Adj SS     Adj MS       F      P
Gum/protein type         4  0,0401100  0,0401100  0,0100275  263,93  0,000
conc                     2  0,0134010  0,0134010  0,0067005  176,36  0,000
Gum/protein type*conc    8  0,0070837  0,0070837  0,0008855   23,31  0,000
Error                   15  0,0005699  0,0005699  0,0000380
Total                   29  0,0611646


S = 0,00616382   R-Sq = 99,07%   R-Sq(adj) = 98,20%


Unusual Observations for sg

Obs       sg      Fit   SE Fit  Residual  St Resid
 23  0,96281  0,97521  0,00436  -0,01240     -2,84 R
 24  0,98760  0,97521  0,00436   0,01240      2,84 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type  N  Mean  Grouping
crbguar           6   1,0  A
crbsoy            6   1,0    B
crbcontrol        6   1,0      C
crbxanthan        6   1,0        D
crbwhey           6   0,9        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
30    10   1,0  A
20    10   1,0    B
10    10   1,0      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type  conc  N  Mean  Grouping
crbguar             30  2   1,1  A
crbguar             20  2   1,0    B
crbcontrol          30  2   1,0    B C
crbsoy              30  2   1,0    B C
crbguar             10  2   1,0    B C
crbsoy              20  2   1,0      C
crbxanthan          30  2   1,0        D
crbcontrol          20  2   1,0        D E
crbwhey             30  2   0,9          E F
crbwhey             10  2   0,9          E F
crbsoy              10  2   0,9          E F
crbwhey             20  2   0,9          E F
crbcontrol          10  2   0,9          E F
crbxanthan          10  2   0,9            F
crbxanthan          20  2   0,9            F
```

Table A. 25 Three way ANOVA and Tukey's Comparison Test for specific gravity values of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

```
Factor            Type   Levels  Values
gum/protein type  fixed       5  control; guar; soy; whey; xanthan
flour             fixed       2  bck; crb
conc              fixed       3  10; 20; 30


Analysis of Variance for sg, using Adjusted SS for Tests

Source                   DF     Seq SS     Adj SS     Adj MS       F      P
gum/protein type          4  0,0639012  0,0639012  0,0159753  234,14  0,000
flour                     1  0,0005636  0,0005636  0,0005636    8,26  0,007
conc                      2  0,0279106  0,0279106  0,0139553  204,53  0,000
gum/protein type*flour    4  0,0043310  0,0043310  0,0010828   15,87  0,000
gum/protein type*conc     8  0,0042358  0,0042358  0,0005295    7,76  0,000
flour*conc                2  0,0011963  0,0011963  0,0005981    8,77  0,001
gum/proteintype*flour*conc 8 0,0050071  0,0050071  0,0006259  9,17  0,000
Error                    30  0,0020469  0,0020469  0,0000682
Total                    59  0,1091924


S = 0,00826016   R-Sq = 98,13%   R-Sq(adj) = 96,31%


Unusual Observations for sg

Obs       sg      Fit   SE Fit  Residual  St Resid
 13  0,97314  0,99174  0,00584  -0,01860     -3,18 R
 14  1,01033  0,99174  0,00584   0,01860      3,18 R
 23  1,00826  1,02479  0,00584  -0,01653     -2,83 R
 24  1,04132  1,02479  0,00584   0,01653      2,83 R
 53  0,96281  0,97521  0,00584  -0,01240     -2,12 R
 54  0,98760  0,97521  0,00584   0,01240      2,12 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type    N  Mean  Grouping
guar                  12   1,0  A
soy            12   1,0    B
control        12   1,0      C
xanthan        12   1,0      C
whey           12   1,0        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

flour   N  Mean  Grouping
bck    30   1,0  A
crb    30   1,0    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
```

30	20	1,0	A
20	20	1,0	B
10	20	1,0	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	flour	N	Mean	Grouping
guar	crb	6	1,0	A
guar	bck	6	1,0	A
soy	bck	6	1,0	B
soy	crb	6	1,0	B
xanthan	bck	6	1,0	B
control	crb	6	1,0	B C
control	bck	6	1,0	C D
whey	bck	6	1,0	D E
xanthan	crb	6	1,0	E
whey	crb	6	0,9	E

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	conc	N	Mean	Grouping
guar	30	4	1,1	A
guar	20	4	1,0	B
soy	30	4	1,0	C
guar	10	4	1,0	C D
control	30	4	1,0	C D
soy	20	4	1,0	D
xanthan	30	4	1,0	D
control	20	4	1,0	E
xanthan	20	4	1,0	E
whey	20	4	1,0	E F
soy	10	4	1,0	E F G
whey	30	4	1,0	E F G
control	10	4	0,9	E F G
xanthan	10	4	0,9	F G
whey	10	4	0,9	G

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	conc	N	Mean	Grouping
bck	30	10	1,0	A
crb	30	10	1,0	A
bck	20	10	1,0	B
crb	20	10	1,0	C
crb	10	10	1,0	D
bck	10	10	1,0	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	flour	conc	N	Mean	Grouping
guar	crb	30	2	1,1	A
guar	bck	30	2	1,1	A B
guar	bck	20	2	1,1	A B C
guar	crb	20	2	1,0	B C D

control	crb	30	2	1,0	C D
soy	crb	30	2	1,0	C D E
guar	crb	10	2	1,0	C D E
xanthan	bck	30	2	1,0	D E F
soy	bck	30	2	1,0	D E F
soy	crb	20	2	1,0	D E F G
guar	bck	10	2	1,0	D E F G H
soy	bck	20	2	1,0	E F G H I
xanthan	bck	20	2	1,0	F G H I
control	bck	30	2	1,0	G H I
whey	bck	20	2	1,0	H I J
xanthan	crb	30	2	1,0	H I J
soy	bck	10	2	1,0	I J
whey	bck	30	2	1,0	I J K
control	bck	20	2	1,0	I J K
control	crb	20	2	1,0	I J K
control	bck	10	2	0,9	J K L
whey	crb	30	2	0,9	J K L
whey	crb	10	2	0,9	J K L
soy	crb	10	2	0,9	J K L
whey	crb	20	2	0,9	J K L
control	crb	10	2	0,9	J K L
xanthan	bck	10	2	0,9	J K L
xanthan	crb	20	2	0,9	K L
xanthan	crb	10	2	0,9	K L
whey	bck	10	2	0,9	L

Table A. 26 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by 10% buckwheat conc and with gums and proteins

Source	DF	SS	MS	F	P
Cake batter	4	2,7473	0,6868	42,62	0,000
Error	5	0,0806	0,0161		
Total	9	2,8279			

S = 0,1269   R-Sq = 97,15%   R-Sq(adj) = 94,87%

```
                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  --------+---------+---------+---------+-
bck.10.control   2  4,8959  0,1826                            (---*--)
bck.10.guar      2  3,3375  0,0530  (---*--)
bck.10.soy       2  4,4625  0,0530                     (--*---)
bck.10.whey      2  4,4150  0,1202                    (---*--)
bck.10.xanthan   2  4,0165  0,1648             (---*---)
                                   --------+---------+---------+---------+-
                                         3,60      4,20      4,80      5,40
```

Pooled StDev = 0,1269

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
bck.10.control	2	4,8959	A
bck.10.soy	2	4,4625	A B
bck.10.whey	2	4,4150	A B
bck.10.xanthan	2	4,0165	B
bck.10.guar	2	3,3375	C

Table A. 27 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by 20% buckwheat conc and with gums and proteins

```
Source           DF       SS       MS      F      P
Cake batter       4  0,59462  0,14866  26,14  0,002
Error             5  0,02844  0,00569
Total             9  0,62306

S = 0,07542   R-Sq = 95,44%   R-Sq(adj) = 91,78%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  -------+---------+---------+---------+--
bck.20.control  2  3,7000  0,1061                      (----*----)
bck.20.guar     2  3,2125  0,0177  (-----*----)
bck.20.soy      2  3,7875  0,0530                         (-----*----)
bck.20.whey     2  3,9250  0,1061                               (----*----)
bck.20.xanthan  2  3,7625  0,0530                        (-----*----)
                                   -------+---------+---------+---------+--
                                        3,25      3,50      3,75      4,00

Pooled StDev = 0,0754


Grouping Information Using Tukey Method

Cake batter              N    Mean  Grouping
bck.20.whey              2  3,9250  A
bck.20.soy               2  3,7875  A
bck.20.xanthan           2  3,7625  A
bck.20.control           2  3,7000  A
bck.20.guar              2  3,2125    B
```

Table A. 28 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by 30% buckwheat conc and with gums and proteins

```
Source         DF       SS       MS     F      P
Cake batter     4  0,17672  0,04418  9,47  0,015
Error           5  0,02333  0,00467
Total           9  0,20004

S = 0,06830   R-Sq = 88,34%   R-Sq(adj) = 79,01%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  ----+---------+---------+---------+-----
bck.30.control  2  3,6875  0,0177                 (------*-------)
bck.30.guar     2  3,4165  0,0233  (-------*------)
bck.30.soy      2  3,7375  0,0177                     (-------*------)
bck.30.whey     2  3,7375  0,1237                     (-------*------)
bck.30.xanthan  2  3,7915  0,0827                        (-------*-------)
                                   ----+---------+---------+---------+-----
                                     3,36      3,52      3,68      3,84

Pooled StDev = 0,0683


Grouping Information Using Tukey Method

Cake batter     N     Mean  Grouping
```

```
bck.30.xanthan  2  3,79150  A
bck.30.whey     2  3,73750  A
bck.30.soy      2  3,73750  A
bck.30.control  2  3,68750  A B
bck.30.guar     2  3,41650    B
```

Table A. 29 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by buckwheat and rice flour

```
Source          DF        SS       MS      F      P
Cake batter     15  7,78518  0,51901  62,72  0,000
Error           16  0,13239  0,00827
Total           31  7,91757

S = 0,09096   R-Sq = 98,33%   R-Sq(adj) = 96,76%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  ---------+---------+---------+---------+
bck.10.control  2  4,8959  0,1826                              (--*-)
bck.10.guar     2  3,3375  0,0530    (--*-)
bck.10.soy      2  4,4625  0,0530                        (-*--)
bck.10.whey     2  4,4150  0,1202                       (--*-)
bck.10.xanthan  2  4,0165  0,1648                 (-*-)
bck.20.control  2  3,7000  0,1061           (--*-)
bck.20.guar     2  3,2125  0,0177  (--*-)
bck.20.soy      2  3,7875  0,0530             (-*-)
bck.20.whey     2  3,9250  0,1061               (-*--)
bck.20.xanthan  2  3,7625  0,0530            (--*-)
bck.30.control  2  3,6875  0,0177           (-*--)
bck.30.guar     2  3,4165  0,0233       (-*-)
bck.30.soy      2  3,7375  0,0177            (-*--)
bck.30.whey     2  3,7375  0,1237            (-*--)
bck.30.xanthan  2  3,7915  0,0827             (-*-)
rice            2  4,9550  0,0071                               (--*-)
                                   ---------+---------+---------+---------+
                                          3,60      4,20      4,80      5,40

Pooled StDev = 0,0910


Grouping Information Using Tukey Method

Cake batter     N    Mean  Grouping
rice            2  4,9550  A
bck.10.control  2  4,8959  A
bck.10.soy      2  4,4625    B
bck.10.whey     2  4,4150    B
bck.10.xanthan  2  4,0165      C
bck.20.whey     2  3,9250      C
bck.30.xanthan  2  3,7915      C
bck.20.soy      2  3,7875      C
bck.20.xanthan  2  3,7625      C D
bck.30.whey     2  3,7375      C D
bck.30.soy      2  3,7375      C D
bck.20.control  2  3,7000      C D E
bck.30.control  2  3,6875      C D E
bck.30.guar     2  3,4165        D E F
bck.10.guar     2  3,3375          E F
bck.20.guar     2  3,2125            F
```

Table A. 30 Two way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by different buckwheat concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for weight loss, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type	4	2,34113	2,34113	0,58528	66,34	0,000
conc	2	2,01431	2,01431	1,00715	114,15	0,000
Gum/ protein type*conc	8	1,17756	1,17756	0,14720	16,68	0,000
Error	15	0,13234	0,13234	0,00882		
Total	29	5,66534				

S = 0,0939301   R-Sq = 97,66%   R-Sq(adj) = 95,48%

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
control	6	4,1	A
whey	6	4,0	A
soy	6	4,0	A B
xanthan	6	3,9	B
guar	6	3,3	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	10	4,2	A
20	10	3,7	B
30	10	3,7	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
control	10	2	4,9	A
soy	10	2	4,5	B
whey	10	2	4,4	B
xanthan	10	2	4,0	C
whey	20	2	3,9	C
xanthan	30	2	3,8	C D
soy	20	2	3,8	C D
xanthan	20	2	3,8	C D
soy	30	2	3,7	C D
whey	30	2	3,7	C D
control	20	2	3,7	C D E
control	30	2	3,7	C D E
guar	30	2	3,4	D E F
guar	10	2	3,3	E F
guar	20	2	3,2	F

Table A. 31 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by 10% carob bean conc and with gums and proteins

```
Source          DF        SS        MS      F      P
Cake batter      4  1,40671  0,35168  46,26  0,000
Error            5  0,03801  0,00760
Total            9  1,44472

S = 0,08719   R-Sq = 97,37%   R-Sq(adj) = 95,26%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  -------+---------+---------+---------+--
crb.10.control   2  4,2000  0,0707                   (---*---)
crb.10.guar      2  3,4750  0,0707  (---*---)
crb.10.soy       2  4,0875  0,0177               (---*---)
crb.10.whey      2  4,6500  0,0354                              (---*---)
crb.10.xanthan   2  4,1150  0,1626                (---*---)
                                    -------+---------+---------+---------+--
                                         3,60      4,00      4,40      4,80

Pooled StDev = 0,0872


Grouping Information Using Tukey Method

Cake batter      N    Mean  Grouping
crb.10.whey      2  4,6500  A
crb.10.control   2  4,2000    B
crb.10.xanthan   2  4,1150    B
crb.10.soy       2  4,0875    B
crb.10.guar      2  3,4750      C
```

Table A. 32 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by 20% carob bean conc and with gums and proteins

```
Source         DF       SS       MS      F      P
Cake batt       4  1,3993  0,3498  16,06  0,005
Error           5  0,1089  0,0218
Total           9  1,5082

S = 0,1476   R-Sq = 92,78%   R-Sq(adj) = 87,00%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  ---------+---------+---------+---------+
crb.20.control   2  4,3875  0,1237                      (------*-----)
crb.20.guar      2  3,5250  0,2828  (------*------)
crb.20.soy       2  4,5000  0,1061                         (-----*------)
crb.20.whey      2  4,2875  0,0177                   (------*------)
crb.20.xanthan   2  3,7980  0,0453       (------*------)
                                    ---------+---------+---------+---------+
                                           3,60      4,00      4,40      4,80

Pooled StDev = 0,1476


Grouping Information Using Tukey Method
```

```
Cake batter      N    Mean  Grouping
crb.20.soy       2  4,5000  A
crb.20.control   2  4,3875  A B
crb.20.whey      2  4,2875  A B
crb.20.xanthan   2  3,7980    B C
crb.20.guar      2  3,5250      C
```

Table A. 33 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by 30% carob bean conc and with gums and proteins

```
Source       DF       SS       MS       F      P
Cake batter  4  1,01481  0,25370  116,78  0,000
Error        5  0,01086  0,00217
Total        9  1,02567

S = 0,04661   R-Sq = 98,94%   R-Sq(adj) = 98,09%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  --------+---------+---------+---------+-
crb.30.control   2  4,3250  0,0354                              (--*--)
crb.30.guar      2  3,4300  0,0424  (-*--)
crb.30.soy       2  3,6500  0,0000         (--*-)
crb.30.whey      2  4,0160  0,0707                     (--*--)
crb.30.xanthan   2  3,6375  0,0530        (--*--)
                                    --------+---------+---------+---------+-
                                          3,60      3,90      4,20      4,50

Pooled StDev = 0,0466


Grouping Information Using Tukey Method

Cake batter      N    Mean  Grouping
crb.30.control   2  4,3250  A
crb.30.whey      2  4,0160    B
crb.30.soy       2  3,6500      C
crb.30.xanthan   2  3,6375      C
crb.30.guar      2  3,4300        D
```

Table A. 34 One way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by carob bean flour and rice flour

```
Source       DF       SS       MS      F      P
Cake batter  15  6,07498  0,40500  41,05  0,000
Error        16  0,15785  0,00987
Total        31  6,23283

S = 0,09933   R-Sq = 97,47%   R-Sq(adj) = 95,09%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  ----+---------+---------+---------+-----
crb.10.control   2  4,2000  0,0707                 (--*--)
crb.10.guar      2  3,4750  0,0707   (-*--)
crb.10.soy       2  4,0875  0,0177               (--*--)
crb.10.whey      2  4,6500  0,0354                          (--*--)
crb.10.xanthan   2  4,1150  0,1626               (--*--)
```

```
crb.20.control   2  4,3875  0,1237                      (--*--)
crb.20.guar      2  3,5250  0,2828    (--*-)
crb.20.soy       2  4,5000  0,1061                         (--*--)
crb.20.whey      2  4,2875  0,0177                     (--*--)
crb.20.xanthan   2  3,7980  0,0453         (--*--)
crb.30.control   2  4,3250  0,0354                     (-*--)
crb.30.guar      2  3,4300  0,0424  (--*--)
crb.30.soy       2  3,6500  0,0000      (--*--)
crb.30.whey      2  4,0160  0,0707             (--*--)
crb.30.xanthan   2  3,6375  0,0530      (--*--)
rice             2  4,9550  0,0071                                   (--*--)
                                    ----+---------+---------+---------+-----
                                      3,50      4,00      4,50      5,00
```

Pooled StDev = 0,0993

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
rice	2	4,9550	A
crb.10.whey	2	4,6500	A B
crb.20.soy	2	4,5000	B C
crb.20.control	2	4,3875	B C D
crb.30.control	2	4,3250	B C D
crb.20.whey	2	4,2875	B C D
crb.10.control	2	4,2000	C D
crb.10.xanthan	2	4,1150	C D E
crb.10.soy	2	4,0875	D E
crb.30.whey	2	4,0160	D E F
crb.20.xanthan	2	3,7980	E F G
crb.30.soy	2	3,6500	F G
crb.30.xanthan	2	3,6375	F G
crb.20.guar	2	3,5250	G
crb.10.guar	2	3,4750	G
crb.30.guar	2	3,4300	G

Table A. 35 Two way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for weight loss, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type	4	2,97584	2,97584	0,74396	70,72	0,000
conc	2	0,56413	0,56413	0,28207	26,81	0,000
Gum/ protein type*conc	8	0,84495	0,84495	0,10562	10,04	0,000
Error	15	0,15780	0,15780	0,01052		
Total	29	4,54273				

S = 0,102566   R-Sq = 96,53%   R-Sq(adj) = 93,28%

Unusual Observations for weight loss

moisture

Obs	loss	Fit	SE Fit	Residual	St Resid
15	3,72500	3,52500	0,07253	0,20000	2,76 R
16	3,32500	3,52500	0,07253	-0,20000	-2,76 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
whey	6	4,3	A
control	6	4,3	A
soy	6	4,1	B
xanthan	6	3,9	C
guar	6	3,5	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	10	4,1	A
20	10	4,1	A
30	10	3,8	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
whey	10	2	4,7	A
soy	20	2	4,5	A B
control	20	2	4,4	A B C
control	30	2	4,3	A B C
whey	20	2	4,3	A B C
control	10	2	4,2	B C D
xanthan	10	2	4,1	B C D
soy	10	2	4,1	C D
whey	30	2	4,0	C D E
xanthan	20	2	3,8	D E F
soy	30	2	3,7	E F
xanthan	30	2	3,6	E F
guar	20	2	3,5	F
guar	10	2	3,5	F
guar	30	2	3,4	F

Table A. 36 Three way ANOVA and Tukey's Comparison Test for weight loss of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
type	fixed	2	bck.; crb.
conc	fixed	3	10; 20; 30
gum/protein types	fixed	5	control; guar; soy; whey; xanthan

Analysis of Variance for weight loss, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
type	1	0,32227	0,32227	0,32227	8,11	0,007
conc	2	1,84323	1,84323	0,92162	23,20	0,000

```
gum/protein types        4   5,15893  5,15893  1,28973  32,47  0,000
type*conc                2   0,73520  0,73520  0,36760   9,25  0,001
type*gum/protein types   4   0,15804  0,15804  0,03951   0,99  0,422
conc*gum/protein types   8   0,80321  0,80321  0,10040   2,53  0,026
Error                    38   1,50945  1,50945  0,03972
Total                    59  10,53034


S = 0,199305   R-Sq = 85,67%   R-Sq(adj) = 77,74%


Unusual Observations for weight loss

     moisture
Obs      loss      Fit   SE Fit  Residual  St Resid
  2   5,02500  4,57634  0,12068   0,44866      2,83 R
 32   4,15000  4,51951  0,12068  -0,36951     -2,33 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

type   N  Mean  Grouping
crb.  30   4,0  A
bck.  30   3,9    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10     20   4,2  A
20      20   3,9    B
30      20   3,7    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein types   N  Mean  Grouping
control            12   4,2  A
whey               12   4,2  A
soy                12   4,0  A B
xanthan            12   3,9    B
guar               12   3,4      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

type  conc   N  Mean  Grouping
bck.  10     10   4,2  A
crb.  10     10   4,1  A
crb.  20     10   4,1  A
crb.  30     10   3,8    B
bck.  20     10   3,7    B
bck.  30     10   3,7    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence
```

type	gum/protein types	N	Mean	Grouping
crb.	whey	6	4,3	A
crb.	control	6	4,3	A
bck.	control	6	4,1	A B
crb.	soy	6	4,1	A B
bck.	whey	6	4,0	A B
bck.	soy	6	4,0	A B
bck.	xanthan	6	3,9	B C
crb.	xanthan	6	3,9	B C
crb.	guar	6	3,5	C D
bck.	guar	6	3,3	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	gum/protein types	N	Mean	Grouping
10	control	4	4,5	A
10	whey	4	4,5	A
10	soy	4	4,3	A B
20	soy	4	4,1	A B C
20	whey	4	4,1	A B C
10	xanthan	4	4,1	A B C
20	control	4	4,0	A B C
30	control	4	4,0	B C
30	whey	4	3,9	B C D
20	xanthan	4	3,8	B C D
30	xanthan	4	3,7	C D
30	soy	4	3,7	C D
30	guar	4	3,4	D
10	guar	4	3,4	D
20	guar	4	3,4	D

Table A. 37 One way ANOVA and Tukey's Comparison Test for porosity of cake batters prepared by 10% buckwheat flour and with gums and proteins

Source	DF	SS	MS	F	P
Cake batter	4	0,093961	0,023490	64,31	0,000
Error	5	0,001826	0,000365		
Total	9	0,095788			

S = 0,01911   R-Sq = 98,09%   R-Sq(adj) = 96,57%

```
                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level            N     Mean    StDev  -+---------+---------+---------+--------
bck.10.control   2  0,41300  0,00368           (--*---)
bck.10.guar      2  0,32836  0,01761   (---*--)
bck.10.soy       2  0,36700  0,00990       (---*--)
bck.10.whey      2  0,60810  0,03380                              (---*--)
bck.10.xanthan   2  0,45815  0,01619                (---*--)
                                      -+---------+---------+---------+--------
                                     0,30      0,40      0,50      0,60
```

Pooled StDev = 0,01911

Grouping Information Using Tukey Method

Cake batter   N   Mean Grouping

```
bck.10.whey     2  0,60810  A
bck.10.xanthan  2  0,45815    B
bck.10.control  2  0,41300    B C
bck.10.soy      2  0,36700      C D
bck.10.guar     2  0,32836        D
```

Table A. 38 One way ANOVA and Tukey’s Comparison Test for porosity of cake batters prepared by 20% buckwheat flour and with gums and proteins

```
Source       DF        SS        MS       F      P
Cake batter   4  0,072990  0,018247  131,85  0,000
Error         5  0,000692  0,000138
Total         9  0,073682

S = 0,01176   R-Sq = 99,06%   R-Sq(adj) = 98,31%


                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level           N     Mean    StDev  --+---------+---------+---------+-------
bck.20.control  2  0,39100  0,01273                    (--*--)
bck.20.guar     2  0,24800  0,01414  (--*--)
bck.20.soy      2  0,32900  0,01414            (--*--)
bck.20.whey     2  0,50400  0,00566                                (--*--)
bck.20.xanthan  2  0,41200  0,00990                      (--*-)
                                     --+---------+---------+---------+-------
                                     0,240     0,320     0,400     0,480

Pooled StDev = 0,01176


Grouping Information Using Tukey Method

Cake batter     N     Mean  Grouping
bck.20.whey     2  0,50400  A
bck.20.xanthan  2  0,41200    B
bck.20.control  2  0,39100    B
bck.20.soy      2  0,32900      C
bck.20.guar     2  0,24800        D
```

Table A. 39 One way ANOVA and Tukey’s Comparison Test for porosity of cake batters prepared by 30% buckwheat flour and with gums and proteins

```
Source           DF        SS        MS      F      P
Batter type       4  0,034286  0,008572  29,01  0,001
Error             5  0,001477  0,000295
Total             9  0,035764

S = 0,01719   R-Sq = 95,87%   R-Sq(adj) = 92,56%


                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level           N     Mean    StDev  --------+---------+---------+---------+-
bck.30.control  2  0,31450  0,01909       (----*-----)
bck.30.guar     2  0,28100  0,02263  (----*----)
bck.30.soy      2  0,30465  0,02341      (----*----)
bck.30.whey     2  0,44265  0,00177                           (----*----)
bck.30.xanthan  2  0,37600  0,00707               (-----*----)
                                     --------+---------+---------+---------+-
```

```
                                                       0,300     0,360     0,420     0,480

Pooled StDev = 0,01719


Grouping Information Using Tukey Method

Batter type     N     Mean  Grouping
bck.30.whey     2  0,44265  A
bck.30.xanthan  2  0,37600  A B
bck.30.control  2  0,31450    B C
bck.30.soy      2  0,30465      C
bck.30.guar     2  0,28100      C
```

Table A. 40 One way ANOVA and Tukey's Comparison Test for porosity values of cake batters prepared by buckwheat flour and rice flour

```
Source       DF        SS        MS      F      P
Batter type  15  0,245507  0,016367  65,41  0,000
Error        16  0,004004  0,000250
Total        31  0,249511

S = 0,01582   R-Sq = 98,40%   R-Sq(adj) = 96,89%


                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level           N     Mean    StDev  -+---------+---------+---------+--------
bck.10.control  2  0,41300  0,00368               (-*-)
bck.10.guar     2  0,32836  0,01761        (-*-)
bck.10.soy      2  0,36700  0,00990            (-*-)
bck.10.whey     2  0,60810  0,03380                              (-*-)
bck.10.xanthan  2  0,45815  0,01619                      (-*-)
bck.20.control  2  0,39100  0,01273              (-*-)
bck.20.guar     2  0,24800  0,01414  (-*-)
bck.20.soy      2  0,32900  0,01414        (-*-)
bck.20.whey     2  0,50400  0,00566                        (-*-)
bck.20.xanthan  2  0,41200  0,00990               (-*-)
bck.30.control  2  0,31450  0,01909       (-*-)
bck.30.guar     2  0,28100  0,02263    (-*-)
bck.30.soy      2  0,30465  0,02341      (-*-)
bck.30.whey     2  0,44265  0,00177                     (-*-)
bck.30.xanthan  2  0,37600  0,00707            (-*-)
rice            2  0,41500  0,00283                (-*-)
                                     -+---------+---------+---------+--------
                                     0,24      0,36      0,48      0,60

Pooled StDev = 0,01582


Grouping Information Using Tukey Method

Batter type     N     Mean  Grouping
bck.10.whey     2  0,60810  A
bck.20.whey     2  0,50400    B
bck.10.xanthan  2  0,45815    B C
bck.30.whey     2  0,44265    B C D
rice            2  0,41500      C D E
bck.10.control  2  0,41300      C D E
bck.20.xanthan  2  0,41200      C D E
bck.20.control  2  0,39100        D E F
bck.30.xanthan  2  0,37600          E F G
bck.10.soy      2  0,36700          E F G H
```

bck.20.soy	2	0,32900	F G H I
bck.10.guar	2	0,32836	F G H I
bck.30.control	2	0,31450	G H I
bck.30.soy	2	0,30465	H I J
bck.30.guar	2	0,28100	I J
bck.20.guar	2	0,24800	J

Table A. 41 Two way ANOVA and Tukey's Comparison Test for porosity of cake cake batters prepared by different buckwheat flour concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for porosity, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type	4	0,187904	0,187904	0,046976	176,34	0,000
conc	2	0,042600	0,042600	0,021300	79,96	0,000
Gum/ protein type *conc	8	0,013333	0,013333	0,001667	6,26	0,001
Error	15	0,003996	0,003996	0,000266		
Total	29	0,247833				

S = 0,0163214   R-Sq = 98,39%   R-Sq(adj) = 96,88%

Unusual Observations for porosity

Obs	porosity	Fit	SE Fit	Residual	St Resid
9	0,584200	0,608100	0,011541	-0,023900	-2,07 R
10	0,632000	0,608100	0,011541	0,023900	2,07 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
whey	6	0,5	A
xanthan	6	0,4	B
control	6	0,4	C
soy	6	0,3	D
guar	6	0,3	E

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	10	0,4	A
20	10	0,4	B
30	10	0,3	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

```
Gum/ protein type  conc  N  Mean  Grouping
whey                10   2   0,6  A
whey                20   2   0,5    B
xanthan             10   2   0,5    B C
whey                30   2   0,4    B C D
control             10   2   0,4      C D E
xanthan             20   2   0,4      C D E
control             20   2   0,4        D E F
xanthan             30   2   0,4          E F G
soy                 10   2   0,4          E F G H
soy                 20   2   0,3            F G H I
guar                10   2   0,3            F G H I
control             30   2   0,3              G H I
soy                 30   2   0,3                H I J
guar                30   2   0,3                  I J
guar                20                2   0,2                    J
```

Table A. 42 One way ANOVA and Tukey's Comparison Test for porosity of cake batters prepared by 10% carob bean flour and with gums and proteins

```
Source        DF        SS        MS      F      P
Cake batter    4  0,032510  0,008128  12,71  0,008
Error          5  0,003198  0,000640
Total          9  0,035708

S = 0,02529   R-Sq = 91,04%   R-Sq(adj) = 83,88%


                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level            N     Mean    StDev  -----+---------+---------+---------+----
crb.10.control   2  0,32150  0,00354   (-------*-------)
crb.10.guar      2  0,31450  0,01485  (------*-------)
crb.10.soy       2  0,34300  0,02828       (------*-------)
crb.10.whey      2  0,46150  0,02758                          (-------*-------)
crb.10.xanthan   2  0,41150  0,03748                  (-------*------)
                                     -----+---------+---------+---------+----
                                        0,300     0,360     0,420     0,480

Pooled StDev = 0,02529


Grouping Information Using Tukey Method

Cake batter      N     Mean  Grouping
crb.10.whey      2  0,46150  A
crb.10.xanthan   2  0,41150  A B
crb.10.soy       2  0,34300    B
crb.10.control   2  0,32150    B
crb.10.guar      2  0,31450    B
```

Table A. 43 One way ANOVA and Tukey's Comparison Test for porosity of cake batters prepared by 20% carob bean flour with gums and proteins

```
Source        DF        SS        MS      F      P
Cake batter   4  0,037045  0,009261  19,13  0,003
Error         5  0,002421  0,000484
Total         9  0,039466

S = 0,02201   R-Sq = 93,87%   R-Sq(adj) = 88,96%
```

```
                                          Individual 95% CIs For Mean Based on
                                          Pooled StDev
Level             N     Mean    StDev  ------+---------+---------+---------+---
crb.20.control    2  0,31750  0,00495               (------*------)
crb.20.guar       2  0,24250  0,01202  (-----*------)
crb.20.soy        2  0,26485  0,02581     (------*------)
crb.20.whey       2  0,39500  0,03960                           (------*-----)
crb.20.xanthan    2  0,38200  0,00424                         (------*-----)
                                       ------+---------+---------+---------+---
                                           0,240     0,300     0,360     0,420

Pooled StDev = 0,02201
```

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
crb.20.whey	2	0,39500	A
crb.20.xanthan	2	0,38200	A
crb.20.control	2	0,31750	A B
crb.20.soy	2	0,26485	B
crb.20.guar	2	0,24250	B

Table A. 44 One way ANOVA and Tukey's Comparison Test for porosity of cake batters prepared by 30 % carob bean flour and with gums and proteins

Source	DF	SS	MS	F	P
Cake batter	4	0,046696	0,011674	55,21	0,000
Error	5	0,001057	0,000211		
Total	9	0,047754			

S = 0,01454   R-Sq = 97,79%   R-Sq(adj) = 96,01%

```
                                          Individual 95% CIs For Mean Based on
                                          Pooled StDev
Level             N     Mean    StDev  --+---------+---------+---------+-------
crb.30.control    2  0,37500  0,00424                        (---*--)
crb.30.guar       2  0,22580  0,00849  (---*---)
crb.30.soy        2  0,27550  0,01768          (--*---)
crb.30.whey       2  0,41630  0,02489                                (--*---)
crb.30.xanthan    2  0,34030  0,00594                   (---*--)
                                       --+---------+---------+---------+-------
                                       0,210     0,280     0,350     0,420

Pooled StDev = 0,01454
```

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
crb.30.whey	2	0,41630	A
crb.30.control	2	0,37500	A B
crb.30.xanthan	2	0,34030	B
crb.30.soy	2	0,27550	C
crb.30.guar	2	0,22580	C

Table A. 45 One way ANOVA and Tukey's Comparison Test for porosity of cake batters prepared by carob bean flour and rice flour

```
Source       DF        SS        MS      F      P
Cake batter  15  0,148424  0,009895  20,71  0,000
Error        16  0,007644  0,000478
Total        31  0,156069

S = 0,02186   R-Sq = 95,10%   R-Sq(adj) = 90,51%


                                      Individual 95% CIs For Mean Based on
                                      Pooled StDev
Level             N     Mean    StDev  ------+---------+---------+---------+---
crb.10.control    2  0,32150  0,00354              (---*---)
crb.10.guar       2  0,31450  0,01485             (---*---)
crb.10.soy        2  0,34300  0,02828                 (---*---)
crb.10.whey       2  0,46150  0,02758                               (---*---)
crb.10.xanthan    2  0,41150  0,03748                        (---*----)
crb.20.control    2  0,31750  0,00495              (---*---)
crb.20.guar       2  0,22750  0,03323  (---*----)
crb.20.soy        2  0,26485  0,02581       (---*---)
crb.20.whey       2  0,39500  0,03960                      (---*---)
crb.20.xanthan    2  0,38200  0,00424                     (---*---)
crb.30.control    2  0,37500  0,00424                    (---*---)
crb.30.guar       2  0,22580  0,00849  (---*---)
crb.30.soy        2  0,27550  0,01768        (---*----)
crb.30.whey       2  0,41630  0,02489                         (---*---)
crb.30.xanthan    2  0,34030  0,00594               (----*---)
rice              2  0,41500  0,00283                         (---*---)
                                       ------+---------+---------+---------+---
                                           0,240     0,320     0,400     0,480

Pooled StDev = 0,02186


Grouping Information Using Tukey Method

Cake batter       N     Mean  Grouping
crb.10.whey       2  0,46150  A
crb.30.whey       2  0,41630  A B
rice              2  0,41500  A B
crb.10.xanthan    2  0,41150  A B
crb.20.whey       2  0,39500  A B C
crb.20.xanthan    2  0,38200  A B C
crb.30.control    2  0,37500  A B C
crb.10.soy        2  0,34300    B C D
crb.30.xanthan    2  0,34030    B C D
crb.10.control    2  0,32150      C D
crb.20.control    2  0,31750      C D
crb.10.guar       2  0,31450      C D E
crb.30.soy        2  0,27550        D E F
crb.20.soy        2  0,26485        D E F
crb.20.guar       2  0,22750          E F
crb.30.guar       2  0,22580            F
```

Table A. 46 Two way ANOVA and Tukey's Comparison Test for porosity of cake cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

```
Factor                 Type       Levels  Values
```

```
Gum/ protein type     fixed       5  control; guar; soy; whey; xanthan
conc                  fixed       3  10; 20; 30


Analysis of Variance for porosity, using Adjusted SS for Tests

Source                     DF     Seq SS     Adj SS     Adj MS      F      P
Gum/ protein type          4  0,1060085  0,1060085  0,0265021  52,06  0,000
conc                       2  0,0160573  0,0160573  0,0080287  15,77  0,000
Gum/ protein type *conc    8  0,0152752  0,0152752  0,0019094   3,75  0,013
Error                      15  0,0076364  0,0076364  0,0005091
Total                      29  0,1449774


S = 0,0225631   R-Sq = 94,73%   R-Sq(adj) = 89,82%


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type N  Mean  Grouping
whey              6   0,4  A
xanthan           6   0,4    B
control           6   0,3    B
soy               6   0,3      C
guar              6   0,3      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10     10   0,4  A
30     10   0,3    B
20     10   0,3    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type    conc  N  Mean  Grouping
whey                 10    2   0,5  A
whey                 30    2   0,4  A B
xanthan              10    2   0,4  A B C
whey                 20    2   0,4  A B C D
xanthan              20    2   0,4  A B C D
control              30    2   0,4  A B C D
soy                  10    2   0,3    B C D E
xanthan              30    2   0,3    B C D E
control              10    2   0,3      C D E
control              20    2   0,3        D E F
guar                 10    2   0,3        D E F G
soy                  30    2   0,3          E F G
soy                  20    2   0,3          E F G
guar                 20    2   0,2            F G
guar                 30    2   0,2              G
```

Table A. 47 Three way ANOVA and Tukey's Comparison Test for porosity of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

```
Factor                Type   Levels  Values
```

Gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30
flour	fixed	2	bck; crb

Analysis of Variance for porosity, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type *conc	8	0,011916	0,011916	0,001489	2,00	0,073
Gum/ protein type*flour	4	0,008409	0,008409	0,002102	2,82	0,038
conc*flour	2	0,006754	0,006754	0,003377	4,53	0,017
Gum/ protein type	4	0,285503	0,285503	0,071376	95,75	0,000
conc	2	0,051904	0,051904	0,025952	34,82	0,000
flour	1	0,033197	0,033197	0,033197	44,54	0,000
Error	38	0,028325	0,028325	0,000745		
Total	59	0,426007				

S = 0,0273020   R-Sq = 93,35%   R-Sq(adj) = 89,68%

Unusual Observations for porosity

Obs	porosity	Fit	SE Fit	Residual	St Resid
52	0,301000	0,347235	0,016532	-0,046235	-2,13 R
55	0,297000	0,253394	0,016532	0,043606	2,01 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
whey	12	0,5	A
xanthan	12	0,4	B
control	12	0,4	C
soy	12	0,3	D
guar	12	0,3	E

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	20	0,4	A
20	20	0,3	B
30	20	0,3	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	N	Mean	Grouping
bck	30	0,4	A
crb	30	0,3	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
whey	10	4	0,5	A
whey	20	4	0,4	B

```
xanthan             10    4   0,4    B C
whey                30    4   0,4    B C
xanthan             20    4   0,4    B C D
control             10    4   0,4      C D E
xanthan             30    4   0,4        D E F
soy                 10    4   0,4        D E F
control             20    4   0,4        D E F
control             30    4   0,3        D E F
guar                10    4   0,3          E F G
soy                 20    4   0,3            F G H
soy                 30    4   0,3            F G H
guar                30    4   0,3              G H
guar                20    4   0,2                H

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type  flour  N  Mean  Grouping
whey               bck    6   0,5  A
whey               crb    6   0,4    B
xanthan            bck    6   0,4    B
xanthan            crb    6   0,4    B C
control            bck    6   0,4    B C
control            crb    6   0,3      C D
soy                bck    6   0,3      C D
soy                crb    6   0,3        D E
guar               bck    6   0,3        D E
guar               crb    6   0,3          E

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc  flour   N  Mean  Grouping
10    bck    10   0,4  A
20    bck    10   0,4    B
10    crb    10   0,4    B
30    bck    10   0,3    B C
30    crb    10   0,3      C
20    crb    10   0,3      C
```

Table A. 48 One way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by 10% buckwheat flour conc with gums and proteins

```
Source        DF       SS       MS      F      P
Cake batter    4  0,19499  0,04875  27,38  0,001
Error          5  0,00890  0,00178
Total          9  0,20389

S = 0,04220   R-Sq = 95,63%   R-Sq(adj) = 92,14%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev   -+---------+---------+---------+--------
bck.10.control   2  1,7707  0,0253                (----*----)
bck.10.guar      2  1,5667  0,0896   (----*-----)
bck.10.soy       2  1,7106  0,0063             (----*----)
bck.10.whey      2  1,9840  0,0047                                (----*----)
```

```
bck.10.xanthan  2  1,6619  0,0132          (----*----)
                                   -+---------+---------+---------+--------
                                  1,50      1,65      1,80      1,95

Pooled StDev = 0,0422


Grouping Information Using Tukey Method

Cake batter     N     Mean  Grouping
bck.10.whey     2  1,98400  A
bck.10.control  2  1,77070    B
bck.10.soy      2  1,71055    B C
bck.10.xanthan  2  1,66185    B C
bck.10.guar     2  1,56665      C
```

Table A. 49 One way ANOVA and Tukey's Comparison Test for specific volume of cake cake batters prepared by 20% buckwheat flour conc with gums and proteins

```
Source         DF        SS        MS      F      P
Cake batter     4  0,198795  0,049699  59,61  0,000
Error           5  0,004169  0,000834
Total           9  0,202964

S = 0,02888   R-Sq = 97,95%   R-Sq(adj) = 96,30%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level           N    Mean   StDev  ---------+---------+---------+---------+
bck.20.control  2  1,6815  0,0247                   (--*---)
bck.20.guar     2  1,4145  0,0361  (--*---)
bck.20.soy      2  1,6480  0,0141                (---*--)
bck.20.whey     2  1,8570  0,0028                              (---*--)
bck.20.xanthan  2  1,6610  0,0453                 (---*--)
                                   ---------+---------+---------+---------+
                                         1,50      1,65      1,80      1,95

Pooled StDev = 0,0289


Grouping Information Using Tukey Method

Cake batter     N     Mean  Grouping
bck.20.whey     2  1,85700  A
bck.20.control  2  1,68150    B
bck.20.xanthan  2  1,66100    B
bck.20.soy      2  1,64800    B
bck.20.guar     2  1,41450      C
```

Table A. 50 One way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by 30% buckwheat flour conc with gums and proteins

```
Source       DF        SS        MS       F      P
Cake batter  4  0,194858  0,048715  131,37  0,000
Error        5  0,001854  0,000371
Total        9  0,196712
```

```
S = 0,01926   R-Sq = 99,06%   R-Sq(adj) = 98,30%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  -------+---------+---------+---------+--
bck.30.control   2  1,6235  0,0233              (-*--)
bck.30.guar      2  1,4294  0,0033  (-*--)
bck.30.soy       2  1,6435  0,0280               (--*-)
bck.30.whey      2  1,8617  0,0081                              (-*-)
bck.30.xanthan   2  1,7070  0,0212                   (--*-)
                                    -------+---------+---------+---------+--
                                         1,50      1,65      1,80      1,95

Pooled StDev = 0,0193


Grouping Information Using Tukey Method

Cake batter     N     Mean  Grouping
bck.30.whey     2  1,86170  A
bck.30.xanthan  2  1,70700    B
bck.30.soy      2  1,64350    B C
bck.30.control  2  1,62350      C
bck.30.guar     2  1,42940        D
```

Table A. 51 One way ANOVA and Tukey's Comparison Test for specific volume of cake cake batters prepared by buckwheat flour and rice flour

```
Source         DF        SS        MS      F      P
Cake batter    15  0,643479  0,042899  45,98  0,000
Error          16  0,014927  0,000933
Total          31  0,658406

S = 0,03054   R-Sq = 97,73%   R-Sq(adj) = 95,61%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  --+---------+---------+---------+-------
bck.10.control   2  1,7707  0,0253                   (--*-)
bck.10.guar      2  1,5667  0,0896          (-*--)
bck.10.soy       2  1,7106  0,0063                (--*-)
bck.10.whey      2  1,9840  0,0047                              (-*-)
bck.10.xanthan   2  1,6619  0,0132              (-*-)
bck.20.control   2  1,6815  0,0247               (-*-)
bck.20.guar      2  1,4145  0,0361  (--*-)
bck.20.soy       2  1,6480  0,0141             (-*--)
bck.20.whey      2  1,8570  0,0028                        (-*-)
bck.20.xanthan   2  1,6610  0,0453              (-*-)
bck.30.control   2  1,6235  0,0233            (-*-)
bck.30.guar      2  1,4294  0,0033   (-*--)
bck.30.soy       2  1,6435  0,0280             (-*-)
bck.30.whey      2  1,8617  0,0081                        (-*-)
bck.30.xanthan   2  1,7070  0,0212                (-*--)
rice             2  1,7355  0,0008                 (--*-)
                                    --+---------+---------+---------+-------
                                    1,40      1,60      1,80      2,00

Pooled StDev = 0,0305


Grouping Information Using Tukey Method
```

```
Cake batter      N     Mean  Grouping
bck.10.whey      2  1,98400  A
bck.30.whey      2  1,86170    B
bck.20.whey      2  1,85700    B C
bck.10.control   2  1,77070    B C D
rice             2  1,73545      C D E
bck.10.soy       2  1,71055        D E
bck.30.xanthan   2  1,70700        D E
bck.20.control   2  1,68150        D E F
bck.10.xanthan   2  1,66185        D E F
bck.20.xanthan   2  1,66100        D E F
bck.20.soy       2  1,64800          E F
bck.30.soy       2  1,64350          E F
bck.30.control   2  1,62350          E F
bck.10.guar      2  1,56665            F
bck.30.guar      2  1,42940              G
bck.20.guar      2  1,41450              G
```

Table A. 52 Two way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by different buckwheat flour concs (10%, 20% and 30%) with gums and proteins

```
Factor  Type           Levels  Values
Gum/ protein type      fixed        5      control; guar; soy; whey; xanthan
conc                   fixed        3      10; 20; 30


Analysis of Variance for sv, using Adjusted SS for Tests

Source                    DF    Seq SS    Adj SS    Adj MS       F      P
Gum/ protein type          4  0,558740  0,558740  0,139685  140,37  0,000
conc                       2  0,049354  0,049354  0,024677   24,80  0,000
Gum/ protein type *conc    8  0,029905  0,029905  0,003738    3,76  0,013
Error                     15  0,014927  0,014927  0,000995
Total                     29  0,652926


S = 0,0315453   R-Sq = 97,71%   R-Sq(adj) = 95,58%


Unusual Observations for sv

Obs       sv      Fit    SE Fit  Residual  St Resid
  5  1,63000  1,56665  0,02231   0,06335      2,84 R
  6  1,50330  1,56665  0,02231  -0,06335     -2,84 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type  N  Mean  Grouping
whey               6   1,9  A
control            6   1,7    B
xanthan            6   1,7    B
soy                6   1,7    B
guar               6   1,5      C

Means that do not share a letter are significantly different.
```

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	10	1,7	A
30	10	1,7	B
20	10	1,7	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
whey	10	2	2,0	A
whey	30	2	1,9	A B
whey	20	2	1,9	B
control	10	2	1,8	B C
soy	10	2	1,7	C D
xanthan	30	2	1,7	C D
control	20	2	1,7	C D E
xanthan	10	2	1,7	C D E
xanthan	20	2	1,7	C D E
soy	20	2	1,6	C D E
soy	30	2	1,6	D E
control	30	2	1,6	D E
guar	10	2	1,6	E
guar	30	2	1,4	F
guar	20	2	1,4	F

Table A. 53 One way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by 10% carob bean flour conc with gums and proteins

Source	DF	SS	MS	F	P
Cake batter	4	0,20036	0,05009	8,70	0,018
Error	5	0,02879	0,00576		
Total	9	0,22915			

S = 0,07588   R-Sq = 87,44%   R-Sq(adj) = 77,39%

```
                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level             N    Mean   StDev  --+---------+---------+---------+-------
crb.10. control   2  1,6220  0,0028        (------*------)
crb.10.guar       2  1,4900  0,0396  (-----*------)
crb.10.soy        2  1,7445  0,1223              (------*------)
crb.10.whey       2  1,9115  0,1082                       (------*-----)
crb.10.xanthan    2  1,7585  0,0233               (------*------)
                                     --+---------+---------+---------+-------
                                     1,40      1,60      1,80      2,00
```

Pooled StDev = 0,0759

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
crb.10.whey	2	1,91150	A
crb.10.xanthan	2	1,75850	A B
crb.10.soy	2	1,74450	A B
crb.10. control	2	1,62200	A B

```
crb.10.guar       2  1,49000    B
```

Table A. 54 One way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by 20% carob bean flour conc with gums and proteins

```
Source        DF       SS        MS      F      P
Cake batter   4  0,15518  0,03880  4,04  0,079
Error         5  0,04805  0,00961
Total         9  0,20323

S = 0,09803   R-Sq = 76,36%   R-Sq(adj) = 57,44%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  ----+---------+---------+---------+-----
crb.20.control   2  1,6575  0,0078          (--------*--------)
crb.20.guar      2  1,5050  0,0410  (--------*--------)
crb.20.soy       2  1,6890  0,0849            (-------*--------)
crb.20.whey      2  1,8831  0,1928                     (--------*--------)
crb.20.xanthan   2  1,7640  0,0438               (--------*--------)
                                   ----+---------+---------+---------+-----
                                     1,40      1,60      1,80      2,00

Pooled StDev = 0,0980


Grouping Information Using Tukey Method

Cake batter      N     Mean  Grouping
crb.20.whey      2  1,88315  A
crb.20.xanthan   2  1,76400  A
crb.20.soy       2  1,68900  A
crb.20.control   2  1,65750  A
crb.20.guar      2  1,50500  A
```

Table A. 55 One way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by 30% carob bean flour conc with gums and proteins

```
Source        DF       SS        MS      F      P
Cake batter  4  0,18719  0,04680  18,49  0,003
Error        5  0,01266  0,00253
Total        9  0,19985

S = 0,05031   R-Sq = 93,67%   R-Sq(adj) = 88,60%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean   StDev  --------+---------+---------+---------+-
crb.30.control   2  1,7930  0,0101                      (------*-----)
crb.30.guar      2  1,4727  0,0470  (-----*-----)
crb.30.soy       2  1,5889  0,0329          (-----*-----)
crb.30.whey      2  1,8385  0,0949                         (------*-----)
crb.30.xanthan   2  1,7492  0,0163                    (-----*-----)
                                   --------+---------+---------+---------+-
                                         1,50      1,65      1,80      1,95
```

Pooled StDev = 0,0503

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
crb.30.whey	2	1,83850	A
crb.30.control	2	1,79295	A
crb.30.xanthan	2	1,74920	A B
crb.30.soy	2	1,58885	B C
crb.30.guar	2	1,47270	C

Table A. 56 One way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by carob bean flour and rice flour

Source	DF	SS	MS	F	P
Cake batter	15	0,63550	0,04237	14,53	0,000
Error	16	0,04666	0,00292		
Total	31	0,68216			

S = 0,05400   R-Sq = 93,16%   R-Sq(adj) = 86,75%

Level	N	Mean	StDev
crb.10.control	2	1,6220	0,0028
crb.10.guar	2	1,4900	0,0396
crb.10.soy	2	1,7445	0,1223
crb.10.whey	2	1,9115	0,1082
crb.10.xanthan	2	1,7585	0,0233
crb.20.control	2	1,6575	0,0078
crb.20.guar	2	1,5200	0,0198
crb.20.soy	2	1,6390	0,0141
crb.20.whey	2	1,9832	0,0514
crb.20.xanthan	2	1,7640	0,0438
crb.30.control	2	1,7930	0,0101
crb.30.guar	2	1,4727	0,0470
crb.30.soy	2	1,5889	0,0329
crb.30.whey	2	1,8385	0,0949
crb.30.xanthan	2	1,7492	0,0163
rice	2	1,7355	0,0008

```
                 Individual 95% CIs For Mean Based on Pooled StDev
Level              +---------+---------+---------+---------
crb.10.control            (---*---)
crb.10.guar        (---*----)
crb.10.soy                      (---*---)
crb.10.whey                              (---*---)
crb.10.xanthan                   (---*---)
crb.20.control              (---*---)
crb.20.guar          (---*---)
crb.20.soy                 (---*---)
crb.20.whey                                 (---*---)
crb.20.xanthan                   (---*---)
crb.30.control                     (---*---)
crb.30.guar        (---*---)
crb.30.soy              (---*---)
crb.30.whey                          (---*---)
crb.30.xanthan                  (---*----)
rice                            (---*---)
                   +---------+---------+---------+---------
                 1,40      1,60      1,80      2,00
```

Pooled StDev = 0,0540

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
crb.20.whey	2	1,98315	A
crb.10.whey	2	1,91150	A B
crb.30.whey	2	1,83850	A B C
crb.30.control	2	1,79295	A B C D
crb.20.xanthan	2	1,76400	B C D
crb.10.xanthan	2	1,75850	B C D
crb.30.xanthan	2	1,74920	B C D
crb.10.soy	2	1,74450	B C D
rice	2	1,73545	B C D E
crb.20.control	2	1,65750	C D E F
crb.20.soy	2	1,63900	C D E F
crb.10.control	2	1,62200	D E F
crb.30.soy	2	1,58885	D E F
crb.20.guar	2	1,52000	E F
crb.10.guar	2	1,49000	F
crb.30.guar	2	1,47270	F

Table A. 57 Two way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for sv, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/protein type	4	0,552176	0,552176	0,138044	44,37	0,000
conc	2	0,003098	0,003098	0,001549	0,50	0,617
Gum/protein type *conc	8	0,078143	0,078143	0,009768	3,14	0,027
Error	15	0,046664	0,046664	0,003111		
Total	29	0,680081				

S = 0,0557756   R-Sq = 93,14%   R-Sq(adj) = 86,73%

Unusual Observations for sv

Obs	sv	Fit	SE Fit	Residual	St Resid	
7	1,83100	1,74450	0,03944	0,08650	2,19	R
8	1,65800	1,74450	0,03944	-0,08650	-2,19	R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type	N	Mean	Grouping
whey	6	1,9	A
xanthan	6	1,8	B
control	6	1,7	B C
soy	6	1,7	C
guar	6	1,5	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
20	10	1,7	A
10	10	1,7	A
30	10	1,7	A

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type	conc	N	Mean	Grouping
whey	20	2	2,0	A
whey	10	2	1,9	A B
whey	30	2	1,8	A B C
control	30	2	1,8	A B C D
xanthan	20	2	1,8	A B C D
xanthan	10	2	1,8	B C D
xanthan	30	2	1,7	B C D
soy	10	2	1,7	B C D
control	20	2	1,7	C D E
soy	20	2	1,6	C D E
control	10	2	1,6	C D E
soy	30	2	1,6	D E
guar	20	2	1,5	E
guar	10	2	1,5	E
guar	30	2	1,5	E

Table A. 58 Three way ANOVA and Tukey's Comparison Test for specific volume of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
flour	fixed	2	bck; crb
gum/protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for sv, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
flour	1	0,006469	0,006469	0,006469	1,83	0,184
gum/protein type	4	1,095545	1,095545	0,273886	77,61	0,000
conc	2	0,028856	0,028856	0,014428	4,09	0,025
flour*gum/protein type	4	0,015370	0,015370	0,003843	1,09	0,376
flour*conc	2	0,023597	0,023597	0,011799	3,34	0,046
gum/protein type*conc	8	0,035543	0,035543	0,004443	1,26	0,293
Error	38	0,134095	0,134095	0,003529		
Total	59	1,339475				

S = 0,0594039   R-Sq = 89,99%   R-Sq(adj) = 84,46%

Unusual Observations for sv

Obs	sv	Fit	SE Fit	Residual	St Resid
37	1,83100	1,69547	0,03597	0,13553	2,87 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	N	Mean	Grouping
crb	30	1,7	A
bck	30	1,7	A

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type	N	Mean	Grouping
whey	12	1,9	A
xanthan	12	1,7	B
control	12	1,7	B
soy	12	1,7	B
guar	12	1,5	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
10	20	1,7	A
20	20	1,7	A B
30	20	1,7	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	gum/protein type	N	Mean	Grouping
crb	whey	6	1,9	A
bck	whey	6	1,9	A
crb	xanthan	6	1,8	B
bck	control	6	1,7	B
crb	control	6	1,7	B
bck	xanthan	6	1,7	B
bck	soy	6	1,7	B
crb	soy	6	1,7	B
crb	guar	6	1,5	C
bck	guar	6	1,5	C

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	conc	N	Mean	Grouping
bck	10	10	1,7	A
crb	20	10	1,7	A B
crb	10	10	1,7	A B
crb	30	10	1,7	A B
bck	30	10	1,7	B
bck	20	10	1,7	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

```
gum/protein type  conc  N  Mean  Grouping
whey              10    4   1,9  A
whey              20    4   1,9  A
whey              30    4   1,9  A B
xanthan           30    4   1,7    B C
soy               10    4   1,7    B C
xanthan           20    4   1,7    B C
xanthan           10    4   1,7    B C
control           30    4   1,7    B C
control           10    4   1,7      C
control           20    4   1,7      C D
soy               20    4   1,6      C D
soy               30    4   1,6      C D E
guar              10    4   1,5        D E F
guar              20    4   1,5          E F
guar              30    4   1,5            F
```

Table A. 59 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by 10% buckwheat flour conc with gums and proteins

```
Source          DF        SS       MS       F      P
Batter type      4  16,95685  4,23921  941,08  0,000
Error            5   0,02252  0,00450
Total            9  16,97937

S = 0,06712   R-Sq = 99,87%   R-Sq(adj) = 99,76%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  ------+---------+---------+---------+---
bck.10.control  2  1,4463  0,0946         (*)
bck.10.guar     2  4,5107  0,0250                                    (*)
bck.10.soy      2  2,5449  0,0909                  (*)
bck.10.whey     2  0,6437  0,0293  (*)
bck.10.xanthan  2  2,0132  0,0619              (*)
                                   ------+---------+---------+---------+---
                                       1,2       2,4       3,6       4,8

Pooled StDev = 0,0671


Grouping Information Using Tukey Method

Batter type     N    Mean  Grouping
bck.10.guar     2  4,5107  A
bck.10.soy      2  2,5449    B
bck.10.xanthan  2  2,0132      C
bck.10.control  2  1,4463        D
bck.10.whey     2  0,6437          E
```

Table A. 60 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by 20% buckwheat flour conc with gums and proteins

```
Source        DF        SS       MS        F      P
Batter type    4  12,55303  3,13826  1419,64  0,000
Error          5   0,01105  0,00221
Total          9  12,56409
```

```
S = 0,04702   R-Sq = 99,91%   R-Sq(adj) = 99,84%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StdDev
Level            N    Mean   StdDev   -+---------+---------+---------+--------
bck.20.control  2  1,4399  0,0226        *)
bck.20.guar     2  4,2350  0,0693                                  (*)
bck.20.soy      2  2,4605  0,0587                  (*
bck.20.whey     2  0,9765  0,0474   (*)
bck.20.xanthan  2  2,1320  0,0071              (*)
                                    -+---------+---------+---------+--------
                                   1,0       2,0       3,0       4,0

Pooled StDev = 0,0470


Grouping Information Using Tukey Method

Batter type     N    Mean  Grouping
bck.20.guar     2  4,2350  A
bck.20.soy      2  2,4605    B
bck.20.xanthan  2  2,1320      C
bck.20.control  2  1,4399        D
bck.20.whey     2  0,9765          E
```

Table A. 61 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by 30% buckwheat flour conc with gums and proteins

```
Source        DF       SS       MS        F      P
Batter type    4  9,55314  2,38828  1234,75  0,000
Error          5  0,00967  0,00193
Total          9  9,56281

S = 0,04398   R-Sq = 99,90%   R-Sq(adj) = 99,82%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StdDev
Level            N    Mean   StdDev  -------+---------+---------+---------+--
bck.30.control  2  2,0330  0,0820             (*)
bck.30.guar     2  4,1088  0,0427                                       (*)
bck.30.soy      2  2,7656  0,0033                       (*)
bck.30.whey     2  1,1220  0,0325   (*)
bck.30.xanthan  2  2,4710  0,0071                 (*)
                                   -------+---------+---------+---------+--
                                        1,60      2,40      3,20      4,00

Pooled StDev = 0,0440


Grouping Information Using Tukey Method

Batter type     N    Mean  Grouping
bck.30.guar     2  4,1088  A
bck.30.soy      2  2,7656    B
bck.30.xanthan  2  2,4710      C
bck.30.control  2  2,0330        D
bck.30.whey     2  1,1220          E
```

Table A. 62 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by buckwheat and rice flour

```
Source      DF        SS       MS       F      P
Batter type 15  41,05836  2,73722  987,35  0,000
Error       16   0,04436  0,00277
Total       31  41,10271

S = 0,05265   R-Sq = 99,89%   R-Sq(adj) = 99,79%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level           N    Mean   StDev  -----+---------+---------+---------+----
bck.10.control  2  1,4463  0,0946        (*)
bck.10.guar     2  4,5107  0,0250                                (*
bck.10.soy      2  2,5449  0,0909                   *)
bck.10.whey     2  0,6437  0,0293  *)
bck.10.xanthan  2  2,0132  0,0619             (*
bck.20.control  2  1,4399  0,0226        (*)
bck.20.guar     2  4,2350  0,0693                              *)
bck.20.soy      2  2,4605  0,0587                  (*
bck.20.whey     2  0,9765  0,0474    (*)
bck.20.xanthan  2  2,1320  0,0071              (*
bck.30.control  2  2,0330  0,0820             (*)
bck.30.guar     2  4,1088  0,0427                             *)
bck.30.soy      2  2,7656  0,0033                    (*)
bck.30.whey     2  1,1220  0,0325      *)
bck.30.xanthan  2  2,4710  0,0071                  (*
rice            2  1,4194  0,0333        (*
                                   -----+---------+---------+---------+----
                                      1,2       2,4       3,6       4,8

Pooled StDev = 0,0527


Grouping Information Using Tukey Method

Batter type     N    Mean  Grouping
bck.10.guar     2  4,5107  A
bck.20.guar     2  4,2350    B
bck.30.guar     2  4,1088    B
bck.30.soy      2  2,7656      C
bck.10.soy      2  2,5449        D
bck.30.xanthan  2  2,4710        D
bck.20.soy      2  2,4605        D
bck.20.xanthan  2  2,1320          E
bck.30.control  2  2,0330          E
bck.10.xanthan  2  2,0132          E
bck.10.control  2  1,4463            F
bck.20.control  2  1,4399            F
rice            2  1,4194            F
bck.30.whey     2  1,1220              G
bck.20.whey     2  0,9765              G
bck.10.whey     2  0,6437                H
```

Table A. 63 Two way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by different buckwheat concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
Gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for hardness, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Gum/ protein type	4	38,3160	38,3160	9,5790	3322,40	0,000
conc	2	0,4515	0,4515	0,2257	78,30	0,000
Gum/ protein type *conc	8	0,7471	0,7471	0,0934	32,39	0,000
Error	15	0,0432	0,0432	0,0029		
Total	29	39,5577				

S = 0,0536950   R-Sq = 99,89%   R-Sq(adj) = 99,79%

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	N	Mean	Grouping
guar	6	4,3	A
soy	6	2,6	B
xanthan	6	2,2	C
control	6	1,6	D
whey	6	0,9	E

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
30	10	2,5	A
20	10	2,2	B
10	10	2,2	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
guar	10	2	4,5	A
guar	20	2	4,2	B
guar	30	2	4,1	B
soy	30	2	2,8	C
soy	10	2	2,5	D
xanthan	30	2	2,5	D
soy	20	2	2,5	D
xanthan	20	2	2,1	E
control	30	2	2,0	E
xanthan	10	2	2,0	E
control	10	2	1,4	F
control	20	2	1,4	F
whey	30	2	1,1	G
whey	20	2	1,0	G
whey	10	2	0,6	H

Table A. 64 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by 10% carob bean flour conc with gums and proteins

Source	DF	SS	MS	F	P

```
Batter type      4  17,1258  4,2814  288,94  0,000
Error            5   0,0741  0,0148
Total            9  17,1999

S = 0,1217   R-Sq = 99,57%   R-Sq(adj) = 99,22%


Level             N    Mean   StDev
crb.10. control   2  3,9350  0,0778
crb.10.guar       2  4,6540  0,1174
crb.10.soy        2  3,7200  0,0990
crb.10.whey       2  1,1645  0,1775
crb.10.xanthan    2  1,9505  0,1138

                  Individual 95% CIs For Mean Based on Pooled StDev
Level              -+---------+---------+--------+--------
crb.10. control                             (-*--)
crb.10.guar                                        (--*-)
crb.10.soy                                (-*-)
crb.10.whey        (--*-)
crb.10.xanthan             (--*-)
                   -+---------+---------+---------+--------
                  1,0       2,0       3,0       4,0

Pooled StDev = 0,1217


Grouping Information Using Tukey Method

Batter type       N    Mean  Grouping
crb.10.guar       2  4,6540  A
crb.10. control   2  3,9350    B
crb.10.soy        2  3,7200    B
crb.10.xanthan    2  1,9505      C
crb.10.whey       2  1,1645        D
```

Table A. 65 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by 20% carob bean flour conc with gums and proteins

```
Source       DF        SS       MS       F      P
Batter type  4  10,07027  2,51757  557,98  0,000
Error        5   0,02256  0,00451
Total        9  10,09283

S = 0,06717   R-Sq = 99,78%   R-Sq(adj) = 99,60%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level            N    Mean   StDev  ----+---------+---------+---------+-----
crb.20.control   2  2,1200  0,0283           (*-)
crb.20.guar      2  4,1445  0,0120                                  (-*)
crb.20.soy       2  3,4843  0,0499                          (-*)
crb.20.whey      2  1,4338  0,1100  (-*)
crb.20.xanthan   2  2,0623  0,0839          (-*)
                                    ----+---------+---------+---------+-----
                                      1,60      2,40      3,20      4,00

Pooled StDev = 0,0672


Grouping Information Using Tukey Method
```

```
Batter type      N    Mean  Grouping
crb.20.guar      2  4,1445  A
crb.20.soy       2  3,4843    B
crb.20.control   2  2,1200      C
crb.20.xanthan   2  2,0623      C
crb.20.whey      2  1,4338        D
```

Table A. 66 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by 30% carob bean flour conc with gums and proteins

```
Source        DF        SS       MS        F      P
Batter type    4  15,98389  3,99597  1038,17  0,000
Error          5   0,01925  0,00385
Total          9  16,00314

S = 0,06204   R-Sq = 99,88%   R-Sq(adj) = 99,78%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level             N    Mean   StDev  ------+---------+---------+---------+---
crb.30.control    2  2,1465  0,0092        (*-)
crb.30.guar       2  5,0845  0,0002                                      (*)
crb.30.soy        2  3,1226  0,1220                  (*)
crb.30.whey       2  1,4962  0,0094  (*)
crb.30.xanthan    2  2,0627  0,0646       (-*)
                                     ------+---------+---------+---------+---
                                         2,0       3,0       4,0       5,0

Pooled StDev = 0,0620


Grouping Information Using Tukey Method

Batter type      N    Mean  Grouping
crb.30.guar      2  5,0845  A
crb.30.soy       2  3,1226    B
crb.30.control   2  2,1465      C
crb.30.xanthan   2  2,0627      C
crb.30.whey      2  1,4962        D
```

Table A. 67 One way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by carob bean and rice flour

```
Source         DF        SS       MS       F      P
Batter type    15  47,95422  3,19695  437,18  0,000
Error          16   0,11700  0,00731
Total          31  48,07122

S = 0,08551   R-Sq = 99,76%   R-Sq(adj) = 99,53%


                                    Individual 95% CIs For Mean Based on
                                    Pooled StDev
Level             N    Mean   StDev   -+---------+---------+---------+--------
crb.10.control    2  3,9350  0,0778                          (*)
crb.10.guar       2  4,6540  0,1174                                (*)
crb.10.soy        2  3,7200  0,0990                        (*)
crb.10.whey       2  1,1645  0,1775   (*)
```

```
crb.10.xanthan   2  1,9505  0,1138          (*)
crb.20.control   2  2,1200  0,0283            (*)
crb.20.guar      2  4,1445  0,0120                            (-*)
crb.20.soy       2  3,4843  0,0499                       (*)
crb.20.whey      2  1,4338  0,1100      (*)
crb.20.xanthan   2  2,0623  0,0839           (*)
crb.30.control   2  2,1465  0,0092            (*)
crb.30.guar      2  5,0845  0,0002                                     (*)
crb.30.soy       2  3,1226  0,1220                    (*)
crb.30.whey      2  1,4962  0,0094      (*-)
crb.30.xanthan   2  2,0627  0,0646           (*)
rice             2  1,4194  0,0333      (*)
                                     -+---------+---------+---------+--------
                                     1,2       2,4       3,6       4,8

Pooled StDev = 0,0855


Grouping Information Using Tukey Method

Batter type      N    Mean  Grouping
crb.30.guar      2  5,0845  A
crb.10.guar      2  4,6540    B
crb.20.guar      2  4,1445      C
crb.10.control   2  3,9350      C D
crb.10.soy       2  3,7200        D E
crb.20.soy       2  3,4843          E
crb.30.soy       2  3,1226            F
crb.30.control   2  2,1465              G
crb.20.control   2  2,1200              G
crb.30.xanthan   2  2,0627              G
crb.20.xanthan   2  2,0623              G
crb.10.xanthan   2  1,9505              G
crb.30.whey      2  1,4962                H
crb.20.whey      2  1,4338                H
rice             2  1,4194                H
crb.10.whey      2  1,1645                H
```

Table A. 68 Two way ANOVA and Tukey's Comparison Test for hardness of cake cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

```
Factor              Type   Levels  Values
Gum/protein type    fixed       5  control; guar; soy; whey; xanthan
conc                fixed       3  10; 20; 30


Analysis of Variance for hardness, using Adjusted SS for Tests

Source                  DF   Seq SS   Adj SS  Adj MS        F      P
Gum/protein type         4  38,4593  38,4593  9,6148  1244,43  0,000
conc                     2   0,9972   0,9972  0,4986    64,54  0,000
Gum/protein type *conc   8   4,7206   4,7206  0,5901    76,37  0,000
Error                   15   0,1159   0,1159  0,0077
Total                   29  44,2931


S = 0,0878992   R-Sq = 99,74%   R-Sq(adj) = 99,49%


Unusual Observations for hardness

Obs  hardness      Fit   SE Fit  Residual  St Resid
```

```
  9   1,29000  1,16450  0,06215   0,12550      2,02 R
 10   1,03900  1,16450  0,06215  -0,12550     -2,02 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type  N  Mean  Grouping
guar              6   4,6  A
soy               6   3,4    B
control           6   2,7      C
xanthan           6   2,0        D
whey              6   1,4          E

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10       10   3,1  A
30              10   2,8    B
20              10   2,6      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type  conc  N  Mean  Grouping
guar              30     2   5,1  A
guar              10     2   4,7    B
guar              20     2   4,1      C
control           10     2   3,9      C D
soy               10     2   3,7        D E
soy               20     2   3,5          E
soy               30     2   3,1            F
control           30     2   2,1              G
control           20     2   2,1              G
xanthan           30     2   2,1              G
xanthan           20     2   2,1              G
xanthan           10     2   2,0              G
whey              30     2   1,5                H
whey              20     2   1,4                H
whey              10     2   1,2                H
```

Table A. 69 Three way ANOVA and Tukey's Comparison Test for hardness of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

```
Factor               Type   Levels  Values
flour                fixed       2  bck; crb
Gum/protein type     fixed       5  control; guar; soy; whey; xanthan
conc                 fixed       3  10; 20; 30


Analysis of Variance for hardness, using Adjusted SS for Tests

Source                                DF    Seq SS    Adj SS    Adj MS        F
P
flour                                  1    3,9305    3,9305    3,9305   740,94
0,000
```

```
Gum/protein type                          4   73,8774   73,8774   18,4693   3481,68
0,000
conc                         2   0,5410   0,5410   0,2705    50,99  0,000
flour* Gum/protein type                  4    2,8979    2,8979    0,7245    136,57
0,000
flour*conc                   2   0,9077   0,9077   0,4539    85,56  0,000
Gum/protein type  *conc      8   2,2017   2,2017   0,2752    51,88  0,000
flour* Gum/protein type  *conc8   3,2660   3,2660   0,4083    76,96  0,000
Error                                30   0,1591   0,1591   0,0053
Total                                59  87,7813


S = 0,0728335   R-Sq = 99,82%   R-Sq(adj) = 99,64%


Unusual Observations for hardness

Obs  hardness      Fit   SE Fit  Residual  St Resid
 39   1,29000  1,16450  0,05150   0,12550      2,44 R
 40   1,03900  1,16450  0,05150  -0,12550     -2,44 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

flour   N  Mean  Grouping
crb    30   2,8  A
bck    30   2,3    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type    N  Mean  Grouping
guar               12   4,5  A
soy                12   3,0    B
control            12   2,2      C
xanthan            12   2,1      C
whey               12   1,1        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
10             20   2,7  A
30             20   2,6  A
20             20   2,4    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

flour  Gum/protein type N  Mean  Grouping
crb           guar     6   4,6  A
bck           guar     6   4,3    B
crb           soy      6   3,4      C
crb           control  6   2,7        D
bck           soy      6   2,6          E
bck           xanthan  6   2,2            F
crb           xanthan  6   2,0              G
bck           control  6   1,6                H
```

crb	whey	6	1,4	I
bck	whey	6	0,9	J

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	conc	N	Mean	Grouping
crb	10	10	3,1	A
crb	30	10	2,8	B
crb	20	10	2,6	C
bck	30	10	2,5	D
bck	20	10	2,2	E
bck	10	10	2,2	E

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/protein type	conc	N	Mean	Grouping
guar	30	4	4,6	A
guar	10	4	4,6	A
guar	20	4	4,2	B
soy	10	4	3,1	C
soy	20	4	3,0	C
soy	30	4	2,9	C
control	10	4	2,7	D
xanthan	30	4	2,3	E
xanthan	20	4	2,1	E F
control	30	4	2,1	E F
xanthan	10	4	2,0	F
control	20	4	1,8	G
whey	30	4	1,3	H
whey	20	4	1,2	H
whey	10	4	0,9	I

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	Gum/protein type	conc	N	Mean	Grouping
crb	guar	30	2	5,1	A
crb	guar	10	2	4,7	B
bck	guar	10	2	4,5	B C
bck	guar	20	2	4,2	C D
crb	guar	20	2	4,1	D
bck	guar	30	2	4,1	D
crb	control	10	2	3,9	D E
crb	soy	10	2	3,7	E F
crb	soy	20	2	3,5	F
crb	soy	30	2	3,1	G
bck	soy	30	2	2,8	H
bck	soy	10	2	2,5	H I
bck	xanthan	30	2	2,5	H I
bck	soy	20	2	2,5	I
crb	control	30	2	2,1	J
bck	xanthan	20	2	2,1	J
crb	control	20	2	2,1	J
crb	xanthan	30	2	2,1	J
crb	xanthan	20	2	2,1	J
bck	control	30	2	2,0	J
bck	xanthan	10	2	2,0	J
crb	xanthan	10	2	2,0	J

crb	whey	30	2	1,5	K
bck	control	10	2	1,4	K L
bck	control	20	2	1,4	K L
crb	whey	20	2	1,4	K L
crb	whey	10	2	1,2	L M
bck	whey	30	2	1,1	M
bck	whey	20	2	1,0	M
bck	whey	10	2	0,6	N

Table A. 70 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by 10% buckwheat flour conc with gums and proteins

Source	DF	SS	MS	F	P
Batter type	4	124,46	31,12	21,77	0,002
Error	5	7,15	1,43		
Total	9	131,61			

S = 1,196   R-Sq = 94,57%   R-Sq(adj) = 90,23%

Level	N	Mean	StDev
bck.10.control	2	32,154	0,016
bck.10.guar	2	26,000	1,796
bck.10.soy	2	31,463	0,005
bck.10.whey	2	35,897	1,980
bck.10.xanthan	2	27,461	0,009

```
                Individual 95% CIs For Mean Based on Pooled StDev
Level              ---------+---------+---------+---------+---------
bck.10.control                    (----*-----)
bck.10.guar         (----*----)
bck.10.soy                      (-----*----)
bck.10.whey                                (-----*----)
bck.10.xanthan         (-----*----)
                   ---------+---------+---------+---------+---------
                24,0      28,0      32,0      36,0
```

Pooled StDev = 1,196

Grouping Information Using Tukey Method

Batter type	N	Mean	Grouping
bck.10.whey	2	35,897	A
bck.10.control	2	32,154	A B
bck.10.soy	2	31,463	A B
bck.10.xanthan	2	27,461	B C
bck.10.guar	2	26,000	C

Table A. 71 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by 20% buckwheat flour conc with gums and proteins

Source	DF	SS	MS	F	P
Batter type	4	70,184	17,546	72,76	0,000
Error	5	1,206	0,241		
Total	9	71,390			

S = 0,4911   R-Sq = 98,31%   R-Sq(adj) = 96,96%

```
                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean  StDev  --------+---------+---------+---------+-
bck.20.control   2  33,754  0,400                     (---*---)
bck.20.guar      2  29,312  0,695    (--*---)
bck.20.soy       2  32,160  0,128               (---*--)
bck.20.whey      2  35,852  0,576                              (--*---)
bck.20.xanthan   2  28,849  0,462  (--*---)
                                   --------+---------+---------+---------+-
                                        30,0      32,5      35,0      37,5

Pooled StDev = 0,491


Grouping Information Using Tukey Method

Batter type      N     Mean  Grouping
bck.20.whey      2  35,8515  A
bck.20.control   2  33,7540    B
bck.20.soy       2  32,1605    B
bck.20.guar      2  29,3115      C
bck.20.xanthan   2  28,8490      C
```

Table A. 72 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by 30% buckwheat flour conc with gums and proteins

```
Source        DF      SS      MS      F      P
Batter type    4  53,215  13,304  45,44  0,000
Error          5   1,464   0,293
Total          9  54,679

S = 0,5411   R-Sq = 97,32%   R-Sq(adj) = 95,18%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level            N    Mean  StDev  -------+---------+---------+---------+--
bck.30.control   2  33,451  0,165                   (---*---)
bck.30.guar      2  29,292  0,011  (---*---)
bck.30.soy       2  31,273  0,515         (---*---)
bck.30.whey      2  35,565  0,227                           (---*---)
bck.30.xanthan   2  30,008  1,058     (---*---)
                                   -------+---------+---------+---------+--
                                       30,0      32,5      35,0      37,5

Pooled StDev = 0,541


Grouping Information Using Tukey Method

Batter type      N     Mean  Grouping
bck.30.whey      2  35,5645  A
bck.30.control   2  33,4510  A
bck.30.soy       2  31,2725    B
bck.30.xanthan   2  30,0080    B
bck.30.guar      2  29,2920    B
```

Table A. 73 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by buckwheat flour and rice flour

```
Source         DF       SS      MS      F      P
Batter type    15  267,879  17,859  29,10  0,000
Error          16    9,819   0,614
Total          31  277,697

S = 0,7834   R-Sq = 96,46%   R-Sq(adj) = 93,15%


                                  Individual 95% CIs For Mean Based on
                                  Pooled StDev
Level            N    Mean  StDev  ---------+---------+---------+---------+
bck.10.control   2  32,154  0,016                    (--*--)
bck.10.guar      2  26,000  1,796  (--*---)
bck.10.soy       2  31,463  0,005                  (--*--)
bck.10.whey      2  35,897  1,980                              (---*--)
bck.10.xanthan   2  27,461  0,009      (--*---)
bck.20.control   2  33,754  0,400                        (--*---)
bck.20.guar      2  29,312  0,695           (---*--)
bck.20.soy       2  32,160  0,128                    (--*--)
bck.20.whey      2  35,852  0,576                              (--*---)
bck.20.xanthan   2  28,849  0,462          (--*---)
bck.30.control   2  33,451  0,165                       (---*--)
bck.30.guar      2  29,292  0,011           (---*--)
bck.30.soy       2  31,273  0,515                 (--*---)
bck.30.whey      2  35,565  0,227                             (---*--)
bck.30.xanthan   2  30,008  1,058             (---*--)
rice             2  29,470  0,057            (--*---)
                                   ---------+---------+---------+---------+
                                         28,0      31,5      35,0      38,5

Pooled StDev = 0,783


Grouping Information Using Tukey Method

Batter type      N    Mean  Grouping
bck.10.whey      2  35,897  A
bck.20.whey      2  35,852  A
bck.30.whey      2  35,565  A
bck.20.control   2  33,754  A B
bck.30.control   2  33,451  A B
bck.20.soy       2  32,160    B C
bck.10.control   2  32,154    B C
bck.10.soy       2  31,463    B C D
bck.30.soy       2  31,273    B C D
bck.30.xanthan   2  30,008      C D E
rice             2  29,470      C D E
bck.20.guar      2  29,312      C D E
bck.30.guar      2  29,292      C D E
bck.20.xanthan   2  28,849        D E F
bck.10.xanthan   2  27,461          E F
bck.10.guar      2  26,000            F
```

Table A. 74 Two way ANOVA and Tukey's Comparison Test for color of cake batters prepared by different buckwheat flour concs (10%, 20% and 30%) with gums and proteins

```
Factor            Type   Levels  Values
gum/protein type fixed     5      bckcontrol;bckguar;bcksoy;bckwhey;bckxanth
conc             fixed     3      10; 20; 30


Analysis of Variance for color, using Adjusted SS for Tests

Source                  DF   Seq SS   Adj SS  Adj MS      F      P
gum/protein type        4  235,219  235,219  58,805  89,86  0,000
conc                    2   12,294   12,294   6,147   9,39  0,002
gum/protein type*conc   8   12,645   12,645   1,581   2,42  0,067
Error                   15    9,816    9,816   0,654
Total                   29  269,973


S = 0,808933   R-Sq = 96,36%   R-Sq(adj) = 92,97%


Unusual Observations for color

Obs    color      Fit  SE Fit  Residual  St Resid
  5  27,2700  26,0000  0,5720    1,2700      2,22 R
  6  24,7300  26,0000  0,5720   -1,2700     -2,22 R
  9  37,2970  35,8970  0,5720    1,4000      2,45 R
 10  34,4970  35,8970  0,5720   -1,4000     -2,45 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type  N  Mean  Grouping
bckwhey           6  35,8  A
bckcontrol        6  33,1    B
bcksoy            6  31,6      C
bckxanthan        6  28,8        D
bckguar           6  28,2        D

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
20     10  32,0  A
30      10  31,9  A
10      10  30,6    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type  conc          N  Mean  Grouping
bckwhey           10     2  35,9  A
bckwhey           20     2  35,9  A
bckwhey           30     2  35,6  A
bckcontrol        20     2  33,8  A B
bckcontrol        30     2  33,5  A B
bcksoy            20     2  32,2    B C
bckcontrol        10     2  32,2    B C
bcksoy            10     2  31,5    B C D
bcksoy            30     2  31,3    B C D
bckxanthan        30     2  30,0      C D E
bckguar           20     2  29,3      C D E
bckguar           30     2  29,3      C D E
```

```
bckxanthan        20     2  28,8         D E F
bckxanthan        10     2  27,5           E F
bckguar           10     2  26,0             F
```

Table A. 75 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by 10% carob bean flour conc with gums and proteins

```
Source          DF      SS      MS      F      P
Cake batter      4  73,714  18,429  49,46  0,000
Error            5   1,863   0,373
Total            9  75,577

S = 0,6104   R-Sq = 97,54%   R-Sq(adj) = 95,56%


Level             N    Mean  StDev
crb.10.control    2  50,617  0,051
crb.10.guar       2  46,337  0,702
crb.10.soy        2  48,325  0,233
crb.10.whey       2  50,955  0,025
crb.10.xanthan    2  43,710  1,146

                 Individual 95% CIs For Mean Based on Pooled StDev
Level               +---------+---------+---------+---------
crb.10.control                                   (---*----)
crb.10.guar                     (---*----)
crb.10.soy                              (---*----)
crb.10.whey                                       (----*---)
crb.10.xanthan      (----*---)
                    +---------+---------+---------+---------
                 42,5      45,0      47,5      50,0

Pooled StDev = 0,610


Grouping Information Using Tukey Method

Cake batter       N    Mean  Grouping
crb.10.whey       2  50,955  A
crb.10.control    2  50,617  A B
crb.10.soy        2  48,325    B C
crb.10.guar       2  46,337      C
crb.10.xanthan    2  43,710        D
```

Table A. 76 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by 20% carob bean flour conc with gums and proteins

```
Source           DF     SS    MS     F      P
Cake batter       4  26,34  6,58  5,15  0,051
Error             5   6,39  1,28
Total             9  32,73

S = 1,131   R-Sq = 80,47%   R-Sq(adj) = 64,84%


                                   Individual 95% CIs For Mean Based on
                                   Pooled StDev
Level             N    Mean  StDev  -----+---------+---------+---------+----
crb.20.control    2  52,300  0,057                  (---------*----------)
```

```
crb.20.guar      2  49,492  0,022    (---------*----------)
crb.20.soy       2  49,422  1,995    (---------*---------)
crb.20.whey      2  52,888  1,360                     (---------*----------)
crb.20.xanthan   2  49,040  0,750  (---------*---------)
                                   -----+---------+---------+---------+----
                                     48,0      50,0      52,0      54,0

Pooled StDev = 1,131


Grouping Information Using Tukey Method

Cake batter      N    Mean  Grouping
crb.20.whey      2  52,888  A
crb.20.control   2  52,300  A
crb.20.guar      2  49,492  A
crb.20.soy       2  49,422  A
crb.20.xanthan   2  49,040  A
```

Table A. 77 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by 30% carob bean flour conc with gums and proteins

```
Source          DF     SS    MS     F      P
Cake batter      4  18,70  4,68  4,34  0,069
Error            5   5,38  1,08
Total            9  24,09

S = 1,038   R-Sq = 77,65%   R-Sq(adj) = 59,76%



Level            N    Mean  StDev
crb.30.control   2  51,460  0,103
crb.30.guar      2  51,023  0,653
crb.30.soy       2  50,927  1,186
crb.30.whey      2  53,635  1,702
crb.30.xanthan   2  49,387  0,803

                 Individual 95% CIs For Mean Based on Pooled StDev
Level               +---------+---------+---------+---------
crb.30.control              (-------*------)
crb.30.guar                (------*-------)
crb.30.soy                (-------*------)
crb.30.whey                          (-------*------)
crb.30.xanthan      (-------*------)
                    +---------+---------+---------+---------
                 47,5      50,0      52,5      55,0

Pooled StDev = 1,038


Grouping Information Using Tukey Method

Cake batter      N    Mean  Grouping
crb.30.whey      2  53,635  A
crb.30.control   2  51,460  A B
crb.30.guar      2  51,023  A B
crb.30.soy       2  50,927  A B
crb.30.xanthan   2  49,387    B
```

Table A. 78 One way ANOVA and Tukey's Comparison Test for color of cake batters prepared by carob bean flour and rice flour

Source	DF	SS	MS	F	P
Cake batter	15	967,470	64,498	75,64	0,000
Error	16	13,644	0,853		
Total	31	981,113			

S = 0,9234   R-Sq = 98,61%   R-Sq(adj) = 97,31%

Level	N	Mean	StDev
crb.10.control	2	50,617	0,051
crb.10.guar	2	46,337	0,702
crb.10.soy	2	48,325	0,233
crb.10.whey	2	50,955	0,025
crb.10.xanthan	2	43,710	1,146
crb.20.control	2	52,300	0,057
crb.20.guar	2	49,492	0,022
crb.20.soy	2	49,422	1,995
crb.20.whey	2	52,888	1,360
crb.20.xanthan	2	49,040	0,750
crb.30.control	2	51,460	0,103
crb.30.guar	2	51,023	0,653
crb.30.soy	2	50,927	1,186
crb.30.whey	2	53,635	1,702
crb.30.xanthan	2	49,387	0,803
rice	2	29,470	0,057

```
                 Individual 95% CIs For Mean Based on Pooled StDev
Level               +---------+---------+---------+---------
crb.10.control                                    (-*-)
crb.10.guar                                 (-*-)
crb.10.soy                                     (-*-)
crb.10.whey                                        (-*-)
crb.10.xanthan                          (-*-)
crb.20.control                                       (-*-)
crb.20.guar                                      (-*-)
crb.20.soy                                       (-*-)
crb.20.whey                                           (-*-)
crb.20.xanthan                                  (-*-)
crb.30.control                                      (-*)
crb.30.guar                                        (-*-)
crb.30.soy                                         (-*-)
crb.30.whey                                           (-*-)
crb.30.xanthan                                   (-*-)
rice                (-*-)
                    +---------+---------+---------+---------
                 28,0      35,0      42,0      49,0
```

Pooled StDev = 0,923

Grouping Information Using Tukey Method

Cake batter	N	Mean	Grouping
crb.30.whey	2	53,635	A
crb.20.whey	2	52,888	A B
crb.20.control	2	52,300	A B C
crb.30.control	2	51,460	A B C D
crb.30.guar	2	51,023	A B C D
crb.10.whey	2	50,955	A B C D
crb.30.soy	2	50,927	A B C D
crb.10.control	2	50,617	A B C D

```
crb.20.guar      2  49,492    B C D E
crb.20.soy       2  49,422    B C D E
crb.30.xanthan   2  49,387    B C D E
crb.20.xanthan   2  49,040      C D E
crb.10.soy       2  48,325        D E
crb.10.guar      2  46,337          E F
crb.10.xanthan   2  43,710            F
rice             2  29,470              G
```

Table A. 79 Two way ANOVA and Tukey's Comparison Test for color of cake batters prepared by different carob bean flour concs (10%, 20% and 30%) with gums and proteins

```
Factor            Type   Levels  Values
gum/protein type  fixed       5  crbcontrol; crbguar; crbsoy; crbwhey; crbxanthan
conc     fixed       3  10; 20; 30


Analysis of Variance for color, using Adjusted SS for Tests

Source                               DF   Seq SS  Adj SS  Adj MS      F      P
gum/protein type                     4   99,013  99,013  24,753  27,22  0,000
conc                    2   60,919  60,919  30,459  33,50  0,000
gum/protein type*conc   8   19,738  19,738   2,467   2,71  0,046
Error                         15   13,640  13,640   0,909
Total                                29  193,310


S = 0,953601   R-Sq = 92,94%   R-Sq(adj) = 86,36%


Unusual Observations for color

Obs    color      Fit  SE Fit  Residual  St Resid
 17  48,0120  49,4225  0,6743   -1,4105     -2,09 R
 18  50,8330  49,4225  0,6743    1,4105      2,09 R

R denotes an observation with a large standardized residual.


Grouping Information Using Tukey Method and 95,0% Confidence

gum/protein type       N  Mean  Grouping
crbwhey                6  52,5  A
crbcontrol             6  51,5  A
crbsoy          6  49,6    B
crbguar                6  49,0    B C
crbxanthan      6  47,4      C

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence

conc   N  Mean  Grouping
30       10  51,3  A
20              10  50,6  A
10              10  48,0    B

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence
```

gum/protein type	conc	N	Mean	Grouping
crbwhey	30	2	53,6	A
crbwhey	20	2	52,9	A B
crbcontrol	20	2	52,3	A B C
crbcontrol	30	2	51,5	A B C D
crbguar	30	2	51,0	A B C D
crbwhey	10	2	51,0	A B C D
crbsoy	30	2	50,9	A B C D
crbcontrol	10	2	50,6	A B C D
crbguar	20	2	49,5	B C D E
crbsoy	20	2	49,4	B C D E
crbxanthan	30	2	49,4	B C D E
crbxanthan	20	2	49,0	C D E
crbsoy	10	2	48,3	D E
crbguar	10	2	46,3	E F
crbxanthan	10	2	43,7	F

Table A. 80 Three way ANOVA and Tukey's Comparison Test for color of cake batters prepared by different flours (buckwheat and carob bean flour) different concs (10%, 20% and 30%) with gums and proteins

Factor	Type	Levels	Values
flour	fixed	2	bck; crb
gum/ protein type	fixed	5	control; guar; soy; whey; xanthan
conc	fixed	3	10; 20; 30

Analysis of Variance for color, using Adjusted SS for Tests

Source	DF	Seq SS	Adj SS	Adj MS	F	P
flour	1	5116,34	5116,34	5116,34	6543,76	0,000
gum/ protein type	4	308,48	308,48	77,12	98,64	0,000
conc	2	63,23	63,23	31,62	40,44	0,000
flour*gum/ protein type	4	25,75	25,75	6,44	8,23	0,000
flour*conc	2	9,98	9,98	4,99	6,38	0,005
gum/ protein type*conc	8	22,83	22,83	2,85	3,65	0,004
flour*gum/ protein type*conc	8	9,56	9,56	1,19	1,53	0,189
Error	30	23,46	23,46	0,78		
Total	59	5579,62				

S = 0,884231   R-Sq = 99,58%   R-Sq(adj) = 99,17%

Unusual Observations for color

Obs	color	Fit	SE Fit	Residual	St Resid
5	27,2700	26,0000	0,6252	1,2700	2,03 R
6	24,7300	26,0000	0,6252	-1,2700	-2,03 R
9	37,2970	35,8970	0,6252	1,4000	2,24 R
10	34,4970	35,8970	0,6252	-1,4000	-2,24 R
47	48,0120	49,4225	0,6252	-1,4105	-2,26 R
48	50,8330	49,4225	0,6252	1,4105	2,26 R

R denotes an observation with a large standardized residual.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	N	Mean	Grouping
crb	30	50,0	A
bck	30	31,5	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum protein type	N	Mean	Grouping
whey	12	44,1	A
control	12	42,3	B
soy	12	40,6	C
guar	12	38,6	D
xanthan	12	38,1	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

conc	N	Mean	Grouping
30	20	41,6	A
20	20	41,3	A
10	20	39,3	B

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	gum protein type	N	Mean	Grouping
crb	whey	6	52,5	A
crb	control	6	51,5	A
crb	soy	6	49,6	B
crb	guar	6	49,0	B C
crb	xanthan	6	47,4	C
bck	whey	6	35,8	D
bck	control	6	33,1	E
bck	soy	6	31,6	E
bck	xanthan	6	28,8	F
bck	guar	6	28,2	F

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

flour	conc	N	Mean	Grouping
crb	30	10	51,3	A
crb	20	10	50,6	A
crb	10	10	48,0	B
bck	20	10	32,0	C
bck	30	10	31,9	C
bck	10	10	30,6	D

Means that do not share a letter are significantly different.

Grouping Information Using Tukey Method and 95,0% Confidence

Gum/ protein type	conc	N	Mean	Grouping
whey	30	4	44,6	A
whey	20	4	44,4	A
whey	10	4	43,4	A B
control	20	4	43,0	A B C
control	30	4	42,5	A B C D

```
control            10      4  41,4    B C D E
soy                30      4  41,1      C D E F
soy                20      4  40,8      C D E F
guar               30      4  40,2        D E F
soy                10      4  39,9          E F
xanthan            30      4  39,7          E F
guar               20      4  39,4          E F
xanthan            20      4  38,9            F
guar               10      4  36,2              G
xanthan            10      4  35,6              G

Means that do not share a letter are significantly different.


Grouping Information Using Tukey Method and 95,0% Confidence


flour  gum/ protein type     conc      N  Mean  Grouping
crb    whey                  30               2  53,6  A
crb    whey            20               2  52,9  A B
crb    control         20               2  52,3  A B C
crb    control         30               2  51,5  A B C D
crb    guar            30               2  51,0  A B C D
crb    whey            10               2  51,0  A B C D
crb    soy             30               2  50,9  A B C D
crb    control         10               2  50,6  A B C D
crb    guar            20               2  49,5    B C D E
crb    soy             20               2  49,4    B C D E
crb    xanthan         30               2  49,4    B C D E
crb    xanthan         20               2  49,0      C D E
crb    soy             10               2  48,3        D E
crb    guar            10               2  46,3          E F
crb    xanthan         10               2  43,7            F
bck    whey            10               2  35,9              G
bck    whey            20               2  35,9              G
bck    whey            30               2  35,6              G H
bck    control         20               2  33,8              G H I
bck    control         30               2  33,5              G H I J
bck    soy             20               2  32,2                H I J K
bck    control         10               2  32,2                H I J K
bck    soy             10               2  31,5                  I J K
bck    soy             30               2  31,3                  I J K
bck    xanthan         30               2  30,0                    J K L
bck    guar            20               2  29,3                      K L M
bck    guar            30               2  29,3                      K L M
bck    xanthan         20               2  28,8                      K L M
bck    xanthan         10               2  27,5                        L M
bck    guar            10               2  26,0                          M
```

Table A. 81 Pore area fraction of cakes formulated with 10% buckwheat flour

```
Source       DF          SS          MS        F      P
formulation   2  0,0214420  0,0107210  1154,63  0,000
Error         3  0,0000279  0,0000093
Total         5  0,0214699

S = 0,003047   R-Sq = 99,87%   R-Sq(adj) = 99,78%


                              Individual 95% CIs For Mean Based on
                              Pooled StDev
Level    N     Mean    StDev  ------+---------+---------+---------+---
control  2  0,23102  0,00325                      (-*)
```

```
guar      2  0,14480  0,00110  (-*-)
whey      2  0,29041  0,00401                                    (-*)
                               ------+---------+---------+---------+---
                                   0,160     0,200     0,240     0,280

Pooled StDev = 0,00305


Grouping Information Using Tukey Method

formulation  N     Mean  Grouping
whey         2  0,29041  A
control      2  0,23102    B
guar         2  0,14480      C
```