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Usage of Carob Bean Flour in Gluten Free Cakes

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Gluten, known as the main protein found in wheat, barley and rye, gives viscoelasticity to dough. However, people with celiac disease have problems related to the consumption of gluten. In this study, carob bean flour which contains significant amount of dietary fibre, minerals, high amount of amino acids, and very low amount of fat was used in cakes as gluten free flour. The aim was to investigate the effects of partial replacement of rice flour by carob bean flour at different concentrations (10%, 20%, and 30%) and addition of different types of proteins (soy protein and whey protein) on specific gravity and quality of cakes (specific volume, hardness). Batters with added whey protein had always lower specific gravity values. Cakes formulated with whey protein had lower hardness and higher specific volumes. Moreover, it was realized that cakes prepared by 20% carob bean flour had the highest specific volume and lower hardness value. Therefore, cakes with 20% carob bean flour and whey protein can be recommended to be used in gluten free cakes.

1. Introduction

Celiac disease is described as immune mediated disorder of intestinal mucosa that is triggered by protein; gluten (Mendoza, 2005). 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, gluten free goods should be produced (Hamer, 2005).

Carob tree which belongs to Leguminosea family is also known as *Ceratonia siliqua L., Fabaceae*. Carob fruit is composed of two different parts. The first one is dark brown husk, and the second one is seed. 80-90% of the fruit is husk (80-90%) and rest of it is seed (20-10%). Furthermore, 50-60% of the carob fruit is sugar which is mainly sucrose, fructose, and glucose. Because of high sugar content, carob has been used as a sweetener. In addition to the sweetener ability of carob fruit, due to its low price and similar flavor with chocolate and cacao, carob fruit has been used as sugar replacer in chocolate industry (Seczyk et al., 2016). While protein portion of fruit varies 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 phosphorous. Carob bean flour contains high amount of unsaturated fatty acids rather than saturated fatty acids. Furthermore, carob bean flour has high amount of amino acids in varying concentrations (Ayaz et al., 2009). Due to significant amount of dietary fiber, carob bean flour also shows cholesterol lowering ability (Salinas et al., 2015). Moreover, germ of carob flour contains high amount of phytochemicals which are polyphenols, gallotannins and pro-anthocyanins. They prevent the excess amount of reactive oxygen species and free radical formation (Custodio et al., 2011).

Whey protein is a valuable by product 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. In addition to that, whey protein improves colour, flavour, and textural characteristics of the product (Silva et al., 2016). Like other proteins, whey protein has amphiphilic structure which provides stabilizing ability. Soy proteins having high nutritional value has been regarded as an economical source of protein; especially lysine. Furthermore, studies have indicated that soy protein isolate enhanced with sulfur containing amino acid had the same biological value with animal protein such as casein (Majzoobi et al., 2014).

However, there are few studies in the literature that investigates the effect of carob bean flour on gluten free baked product. Therefore, the main objective of the study is to determine the effects of carob bean flour and different proteins (soy protein, and whey protein) on specific gravity of cake batter and quality of cakes.

2. Materials and Methods

2.1 Materials

Rice flour and carob bean flour were obtained from Başak Flour (Ankara, Turkey), and Havancızade (Istanbul, Turkey), respectively. 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 and whey protein concentrate with 80% protein were obtained from Smart Chemical Trading Co. Inc. (Turkey).

2.2 Preparation and analysis of cake batter

Cake batter formulation contained 5% baking powder, 3% salt, 100% sugar, 9% egg white powder, 25% shortening, 3% emulsifier, and 90% water in terms of flour basis. Rice flour replaced with carob bean flour at different concentrations (10, 20, and 30%). In order to see the effect of protein, 3% soy protein concentrate or whey protein concentrate were used interchangeably. Carob bean flour containing cakes without the addition of protein were also used as control.

After dry ingredients were mixed with a mixer (Kitchen Aid5K45SS, USA) for 2 min at 85 rpm, melted shortening was added to the mixture and mixed further at 85 rpm for 5 min.

Specific gravity measurement was carried out as described by Turabi et al. (2008). Certain volume of cake batter was weighed and divided by the weight of water with the same volume.

2.3 Baking and analysis of cake

For baking of cakes, an electrical oven (9411FT, Arçelik Inc. Co., Istanbul, Turkey) was used. Oven temperature was preheated to 175°C and four glass cups each containing 100 g batter were placed into the hot oven. Baking operation took 28 min. After 1 hour, specific volume and texture of cakes were carried out. To measure the specific volume, rape seed displacement method was used (AACC, 1990).

For texture analysis, after being cooled down for 1 hour, cakes were cut into cubic shape having dimensions of $3cm \times 3cm \times 3cm$. To measure the hardness value of cakes, texture analyser with a cylindrical probe having diameter of 1 cm and load cell of 50 N (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.

2.4 Color analysis of cake

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 (1).

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \quad (1)$$

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.

2.5 Statistical Analysis

To decide whether there is a significant difference between percent replacements of rice flour by carob bean flour and the type of proteins used, 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. The correlation coefficient between specific gravity, specific volume and hardness of cakes was expressed by Pearson correlation with 95% confidence level (α=0.05).

3. Results and discussion

3.1 Specific gravity of cake batter

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. The effect of carob bean flour addition, protein type and their interactions on specific gravity of cake batter was shown in Figure 1.

As can be seen, regardless of the carob bean flour concentration used, whey protein added formulations always had the lowest specific gravity, which might be due to the good whipping ability. 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). Soy protein addition did not show the desired effect on specific gravity as whey protein did. This might be due to the low solubility of soy proteins which was strongly related to foaming ability (Kinsella, 1979). Increasing carob bean amount in the formulation led to thicker batter, which might be due to increasing fibre and sugar content. Increasing fibre content might obstruct mixing efficiency and aeration of gas bubbles.

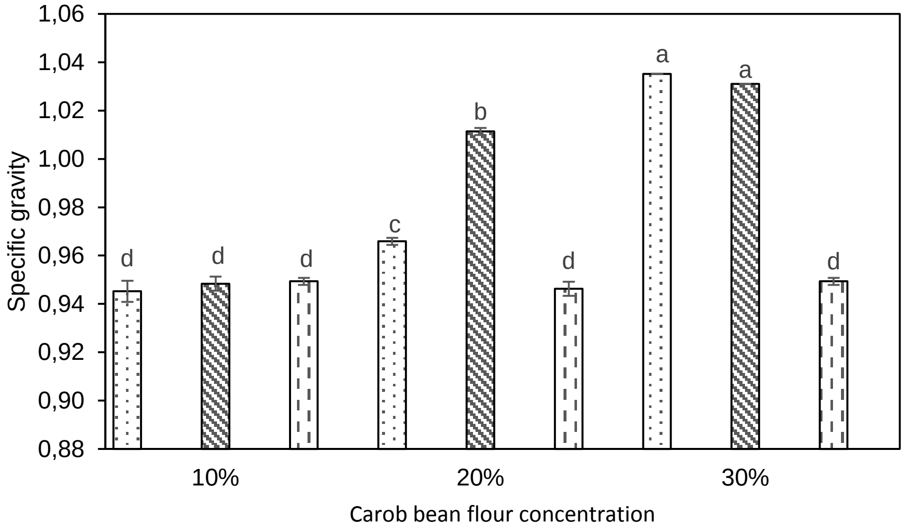

Figure 1: Specific gravity of cake batters prepared with different carob bean flour concentration and protein type, control ( ), soy protein ( ), whey protein ( ). Bars having different letters are significantly different (p≤0.05). Concentrations of carob bean flour are given in terms of flour basis.

3.2 Specific volume of cakes

Volume of cakes is one of the most important quality attribute for consumer. Specific volume of cakes containing carob bean flour with proteins was shown in Figure 2. Specific volume of cakes varied between 1.58 and 1.91 ml/g. The highest volume was obtained by adding whey protein to cakes with 20% carob bean flour. Seyhun et al. (2003) stated that emulsifier helps formation and incorporation of air bubbles during mixing. Emulsifier dispersed in shortening in the form of small particles provides many number of gas cells. For all concentrations of carob bean flour, air incorporation to batter was the highest in whey protein. On the other hand, soy protein addition did not show any enhancing effect on specific volume of cakes. Soy protein added samples had even lower specific volume than control. A study conducted by Marco & Rosell (2008) revealed similar results and showed that bread prepared with soy protein had lower volume, too. According to ANOVA results, although it did not create a significant difference, 20% carob bean flour added samples had relatively higher volume than 10% and 30% carob bean flour containing cakes, respectively.

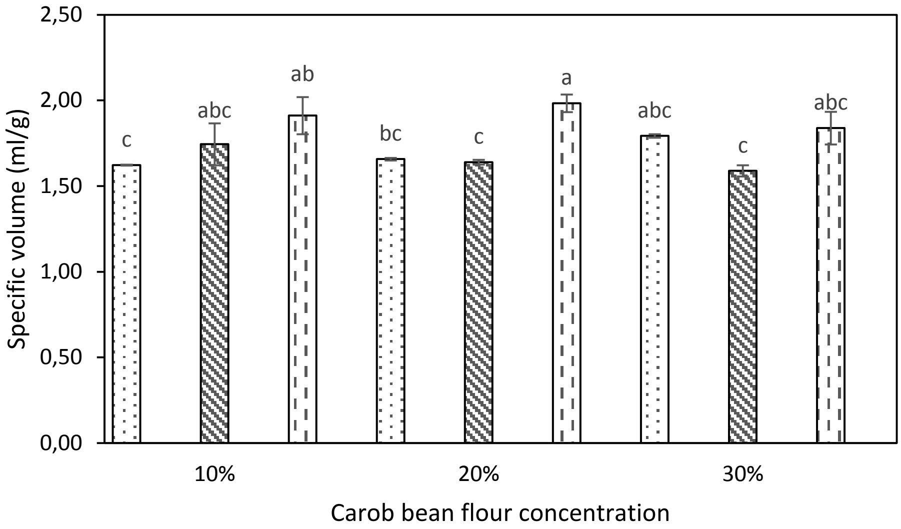

Figure 2: Specific volume of cake batters prepared with different carob bean flour concentration and protein type, control ( ), soy protein ( ), whey protein ( ). Bars having different letters are significantly different (p≤0.05). Concentrations of carob bean flour are given in terms of flour basis.

3.3 Hardness of cakes

Textural analysis of cakes was evaluated in terms of hardness. As can be seen from Figure 3, concentration of flour and protein types had a significant influence on this quality parameter. Hardness results were found to be correlated with specific volume results. Correlation coefficient between specific volume and hardness was -0.728 (p=0.001). It meant that samples with high specific volume had the softest texture, which was a desired case for cake samples. Addition of soy protein to formulation did not improve the texture of gluten free cakes. Similar results were obtained by the study conducted by Crockett (2009). It was stated that disulphide 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 increased hardness of cakes. Whey protein addition decreased hardness of cakes. Furthermore, increasing carob bean flour concentration from 10% to 20% and 30% created significant difference in terms of hardness.

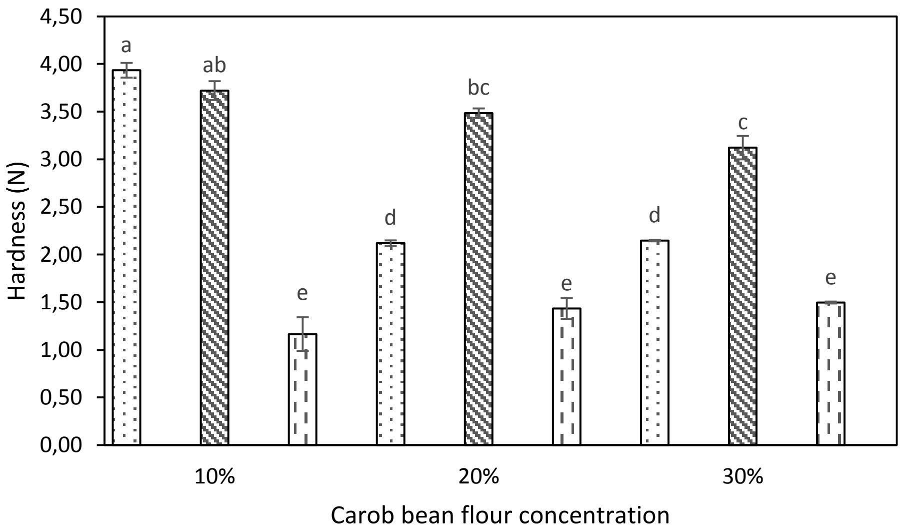

Figure 3: Hardness of cakes prepared with different carob bean flour concentration a protein type, control ( ), soy protein ( ), whey protein ( ). Bars having different letters are significantly different (p≤0.05). Concentrations of carob bean flour are given in terms of flour basis.

Since air incorporation in cake batter during mixing is one of the factors that affects hardness of cakes, increasing carob bean flour concentration in formulation might make incorporation of air in batter difficult with increasing viscosity. This might be due to not only increasing of fibre content but also soluble components in formulation. It was known that carob bean flour has high amount of fibre which was stated that dietary fibre amount in 100 g carob bean flour is 52.8 g (Tsatsaragkou et al. 2014). Due to high water holding capacity of fibre, viscosity of cake batter had tendency to increase with concentration.

3.4 Crust color of cakes

Surface color formation is an important quality parameter together with aroma for product acceptance of consumers (Zanoni et al. 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). 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 carob bean flour in cake, whey protein promoted browning reactions and led to the highest colour change. Furthermore, carob bean flour concentration did not have an effect on colour.

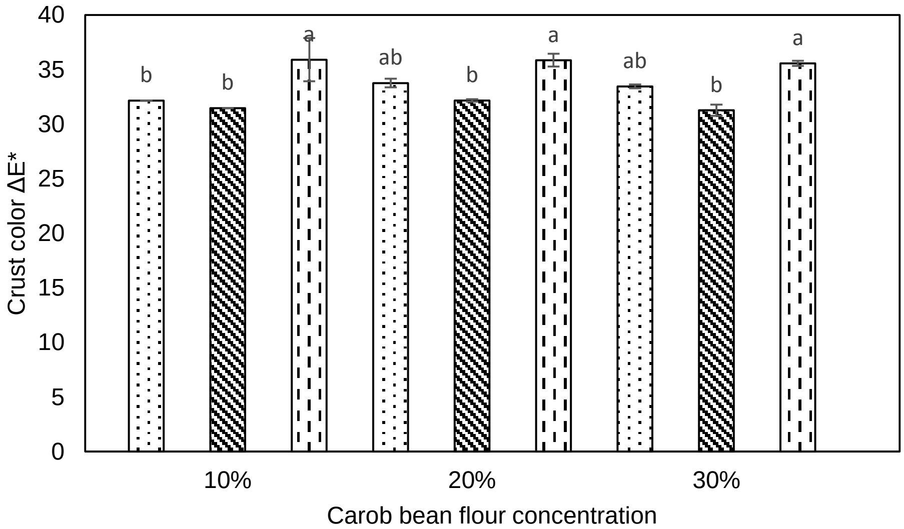

Figure 4: Crust color of cakes with different carob bean flour concentration and protein type, control ( ), soy protein ( ), whey protein ( ). Bars having different letters are significantly different (p≤0.05). Concentrations of carob bean flour are given in terms of flour basis.

4. Conclusion

Addition of whey protein to cake batter decreased specific gravity. On the other hand, increasing carob bean flour concentration resulted in increasing specific volume. Formulations containing soy protein had the lowest volume. In addition to, specific gravity and specific volume results, whey protein added samples had the lowest hardness values. Therefore, cake prepared with 20% carob bean concentration and whey protein had the most acceptable quality parameters. Thus, this formulation can be recommended for celiac patients as gluten free cake.

Reference

AACC, 1990. Approved Methods of the AACC. American Association of Cereal Chemists, St Paul, MN.

Ayaz, F.A., Torun, H., Glew, R.H., Bak, Z.D., Chuang, L.T., Presley, J.M., Andrews, R., 2009. Nutrient content of carob pod (Ceratonia siliqua L.) flour prepared commercially and domestically. Plant Foods for Human Nutrition 64,286–292.

Crockett, R., 2009. The physicochemical properties of gluten-free dough with addition of hydrocolloids and proteins. (Master Thesis, The Ohio State University, USA).

Custodio, L., Escapa, A.L., Fernandes, E., Fajardo, A., Aligue, R., Albericio, F., Neng, N., Nogueira, J.M.F., Romano, A., 2011. Phytochemical Profile, Antioxidant and Cytotoxic Activities of the Carob Tree (Ceratonia siliqua L.) Germ Flour Extracts. Plant Foods for Human Nutrition. 66,78–84.

Hamer, R.J., 2005. Coeliac Disease : Background and biochemical aspects, Biotechnology Advances 23, 401–408.

Kinsella, J.E., 1979. Functional properties of soy proteins. Journal of the American Oil Chemists' Society, 56, 242–248.

Lam, R.S.H. & Nickerson, M.T., 2015. The effect of pH and temperature pre-treatments on the structure, surface characteristics and emulsifying properties of alpha-lactalbumin. Food Chemistry, 173, pp.163–170

Majzoobi, M., Ghiasi, F., Habibi, M., Hedayati, S., Farahnaky, A., 2014. Influence of soy protein ısoalte on the quality of batter and sponge cake. Journal of Food Processing and Preservation. 38,1164–1170.

Mendoza, N., 2005. Coeliac disease : an overview of the diagnosis, treatment and management. British Nutrition and Foundation, 30,231–236

Marco, C. & Rosell, C.M., 2008. Bread making performance of protein enriched, gluten-free breads. European Food Research and Technology, 227, pp.1205–1213.

Purlis, E. & Salvadori, V.O., 2009. Modelling the browning of bread during baking. Food Research International, 42(7), pp.865–870.

Salinas, M. V., Carbas, B., Brites, C., Puppo, M.C., 2015. Influence of Different Carob Fruit Flours (Ceratonia siliqua L.) on Wheat Dough Performance and Bread Quality. Food and Bioprocess Technology. 8,1561–1570.

Seczyk, L., Swieca, M., Sziki- Gawlik, U., 2016. Effect of carob (Ceratonia siliqua L.) flour on the antioxidant potential, nutritional quality, and sensory characteristics of fortified durum wheat pasta. Food Chemistry 194,637–642.

Seyhun, N., Sumnu, G., Sahin, S., 2003. Effects of different emulsifier types , fat contents , and gum types on retardation of staling of microwave-baked cakes. Nahrung/Food 47, 248–251.

Silva, D.A., Marques, G.D.A., Freitas, J., Madeira, E., 2016. Whey protein as a substitute for wheat in the development of no added sugar cookies. Food Science and Technology 67,118–126.

Tsatsaragkou, K., Gounaropoulos, G. & Mandala, I., 2014. Development of gluten free bread containing carob flour and resistant starch. LWT - Food Science and Technology, 58, pp.124–129.

Turabi, E., Sumnu, G., Sahin, S., 2008. Rheological properties and quality of rice cakes formulated with different gums and an emulsifier blend. Food Hydrocolloids, 22,305–312.

Zanoni, B., Peri, C. & Bruno, D., 1995. Modelling of browning kinetics of bread crust during baking. LWT - Food Science and Technology, 28(6), pp.604–609.