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DIELECTRIC AND THERMAL PROPERTIES OF RICE CAKE FORMULATIONS CONTAINING DIFFERENT GUMS TYPES

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In this study, dielectric properties of rice cake formulations containing different gum types (xanthan, guar, locust bean, HPMC, and kappa-carrageenan) were determined at temperatures between 25 and 90°C at 2450 MHz. Moreover, thermal properties of these formulations were determined by using differential scanning calorimeter (DSC). Dielectric properties of cake batters were found to be dependent on cake formulation. Xanthan and guar gum containing cake batters had the highest dielectric constant and loss factor values at 25°C. Temperature dependence of dielectric properties was not significant until temperature of 85°C. Gelatinization enthalpy of batter increased with the addition of gums.

Keywords: ***Rice cake, Gum, Dielectric properties, DSC, Batter***

INTRODUCTION

A lifelong gluten-free diet is essential for patients having gluten sensitive entropathy (GSE) or celiac disease since consuming wheat gluten or similar proteins in other closely related cereals (rye, oat and barley) leads to malabsorption of most nutrients.[1] The number of patients having GSE is estimated as one out of 85–500 people in Europe, which changes depending on the country.[2] Production of low-cost gluten-free food products having the identical quality characteristics as products containing gluten is a crucial point since gluten is the main structure forming protein giving the desired texture and taste to baked products. Microwave processing can bring the advantages of time and energy saving during production of such products.

Rice (Oryza sativa), which has very low level of gluten, low levels of sodium, protein, fat, fiber and high amount of easily digested carbohydrates, is one of the most frequently used cereals as a wheat substitute in gluten-free food products.[3] On the other hand, some food additives such as starches, gums, hydrocolloids, or dairy products should be added to gluten-free product to achieve the desired quality. Gums, which are added to foods for

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mainly their gelling and thickening properties are also used for improving the mouthfeel and changing the viscosity due to their high polymeric nature and the interactions between polymer chains when they are dissolved or dispersed.[4] Five different commercial food grade gums namely xanthan–guar gum blend, carrageenan gum, guar–carrageenan gum blend, xanthan–carrageenan gum blend and locust bean gum, were added to the corn starch to produce low phenylalanine starch–gum bread for phenylketonuria patients in the study of Ozboy.[5] In the study of Turabi et al.,[6] five different gum types, which are xanthan, guar, locust bean, kappa-carrageenan, HPMC, and their blends were added to rice cake formulations to study their rheological properties.

Determination of dielectric properties, which affect the interaction of electromagnetic energy with the material, is important for microwave processing, since heating of a food by microwave energy is controlled by its dielectric properties. Moreover, knowledge of dielectric properties also plays a critical role in developing product, process, and equipment with consistent and predictable properties. The main dielectric properties are dielectric constant and dielectric loss factor. Dielectric constant is a measure of the ability of a material to store electrical energy, and loss factor is a measure of the ability of a material to convert electromagnetic energy into heat. A study on dielectric properties of different starch species, including rice starch[7] showed that the dielectric properties were dependent on temperature, moisture content and starch type. A study on dielectric properties of starch and rice flour slurries can also be found in the literature.[8] In the study of Ahmed et al.[8] a sharp change in the dielectric properties of Indian Basmati rice flour slurry were noted above 70°C, which was attributable to rice starch gelatinization. There are limited studies on dielectric properties of cake batter and bread dough and in these studies, samples were all wheat based. In the study of Sakiyan et al.[9] the variation of dielectric properties of different cake formulations during baking in microwave and infrared-microwave combination oven was investigated. Similarly, the effects of different gums on dielectric properties and quality of breads baked in infrared-microwave combination oven were studied by Keskin et al.[10] Dielectric properties of other types of foods were also investigated in several studies such as dielectric properties of pumpable foods at 915 MHz in the study of Coronel et al.[11] and mashed potatoes in the study of Regier et al.[12]

Study of thermal properties can provide guides for processing and utilization of starch and also information for exploring and understanding the structure of starch. Differential scanning calorimeter (DSC) is a powerful instrument used for understanding the thermal and gelatinization properties of starch or water-flour systems. Analysis of DSC data can also provide information about starch, such as its structure and composition, its interaction with other components, the effects of water, and related properties. There are many studies in the literature, which investigated thermal properties of many starch and flour types. On the other hand, studies are limited for batter systems containing different types of flours. In the study of Xue and Ngadi,[13] thermal properties such as glass transition and gelatinization temperatures, enthalpy and heat capacity changes of batter systems formulated by combinations of different flours were investigated. The functionalities of hydrocolloid-flour mixtures in terms of the thermal properties were investigated in the study of Xue and Ngadi.[14] In the study of Rojas et al.,[15] the effect of several hydrocolloids on the pasting properties and gelling behaviour of wheat flour was investigated by using DSC.

In the literature, there is negligible research on dielectric and thermal properties of gluten-free rice cake batters containing different types of gums. In order to understand the heating behavior of cake batters during baking by using electromagnetic waves, it is important to determine the dielectric and thermal properties. Therefore, the main objectives of this study were to determine dielectric and thermal properties of gluten-free cake batters containing different gums and to understand the effect of temperature on these properties.

MATERIALS AND METHODS

Materials

Rice flour (Knorr-Çapamarka, Istanbul, Turkey), sugar, shortening (Rama, Hamburg, Germany), salt, and baking powder (Ruf, Quakenbrück, Germany) were bought from local market. Egg white powder was obtained from Igreca (Seiches sur le Loir, France). Xanthan gum was obtained from Fluka, BioChemika (Germany), guar gum and locust bean gum were obtained from Sigma-Aldrich Chemical Company Inc. (Germany). HPMC and kappa-carrageenan were obtained from Dow Chemical Company (Germany) and FMC Biopolymer Company (Drammen, Norway), respectively.

Preparation of the Cake

A cake batter recipe containing 100 g rice flour, 100 g sugar, 9 g egg white powder, 3 g salt, 5 g baking powder, 25 g shortening, 90 g water, and 1 g gum was used in the experiments. The types of gums used were xanthan gum, guar gum, xanthan-guar gum blend, locust bean gum, kappa- carrageenan, xanthan-kappa-carrageenan blend, and HPMC. Gum blends contained equal amounts of each type. A cake batter containing no gum was prepared as a control batter.

During preparation of the cake, firstly dry ingredients (rice flour, baking powder, salt, and gum blend) were mixed thoroughly. Then, sugar and egg white powder were mixed in another container and melted shortening was added to sugar-egg white powder blend. By using a mixer (Kenwood Chef, Germany), shortening, sugar, and egg white powder were mixed for 1 min at level 1. Dry ingredient mix and water were added simultaneously and mixed first for 2 min at level 1, then 1 min for level 2 and finally 2 min at level 1.

Determination of Dielectric Properties

The dielectric properties were measured by using a network analyzer (HP 8753 D, Hewlett Packard Co., Santa Rosa, CA) with an open-ended coaxial line connected to a dielectric probe in a frequency range 2000–3000 MHz. The dielectric properties at 2450 MHz were taken into consideration. The network analyzer was calibrated with air, metallic short and distilled water at 25°C. Dielectric properties of cake batters were measured between temperatures of 25 and 90°C immediately after the batters were prepared. A temperature controlled oil bath was used to reach the desired temperature. All measurements were done in triplicate.

Dielectric properties of the powder forms of gums and rice flour were determined at 2450 MHz at 25°C by using cavity resonator method.[16] A constructed partially filled transversal electric (TE) 011 resonator was connected to a Network Analyzer (Hewlett Packard Co. 8753 D, Santa Rosa, CA), which worked at frequencies between 30 kHz-6 GHz. A computer program written by Regier[16] was used to calculate the dielectric constant and dielectric loss factor values analytically at approximately 2450 MHz.

Determination of Thermal Properties

Thermal properties of the batters were determined using a differential scanning calorimeter (Jade, Perkin Elmer, Waltham, Massachusetts, USA) that was previously calibrated with indium and sapphire. For the measurement, a batter sample (25–30 mg) was placed in hermetically sealed stainless steel pans. An empty pan was used as reference. The samples were heated from 7 to 140°C using a scanning rate of 10°C/min. During the thermal analysis of rice cake batters by using DSC, onset, peak and conclusion temperatures, and enthalpy changes were determined for each type of batter sample containing different gum types.

Determination of Bulk Density

Bulk densities of hydrocolloids and rice flour were measured by using a cup with known volume. The cup was completely filled with the sample by tapping and bulk density (g/cm^3) was calculated by dividing the weight of the sample by the volume of the cup.

Statistical Analysis

One-way analyses of variance (ANOVA) was performed to determine whether there is a significant effect of different gum types ($p \leq 0.05$) on dielectric properties at 25°C. Minitab 14 statistical software (State Collage, PA, USA) was used for all of these statistical analyses.

RESULTS AND DISCUSSION

Addition of different types of gums to the cake formulations was found to be effective on the dielectric constant and loss factor of the cake batter samples according to statistical analysis ($p \leq 0.05$). When dielectric constants of cake batters at 25°C were considered (Table 1), batters containing xanthan and guar gum gave the highest dielectric constant values. Xanthan, guar, and xanthan-guar blend containing batters blend had higher dielectric constant than control cake batter. HPMC and locust bean gum containing cake batters were lower than the other batters. This may be due to the low dielectric constant values of these gums in powder form (Table 2). In Table 3, which shows bulk densities of different gum

Table 1 Onset (T_o), peak (T_p), conclusion (T_c) temperatures of gelatinization, gelatinization enthalpies (ΔH), dielectric constant (ε'), and dielectric loss factor (ε'') values of the rice cake batters.

Formulation	T_o (°C)	T_p (°C)	T_c (°C)	ΔH (j/g)	ε'	ε''
Control	97	110.14	126	1.8455	18.2726	8.9100
X	91	110.67	130	2.4221	19.5613	9.7051
G	92	108.92	132	2.5249	19.2178	9.1121
X+G	94	108.30	126	2.1071	19.8296	9.7020
LBG	91	106.66	125	2.2567	14.4823	8.0792
HPMC	95	107.76	126	2.2661	14.7418	7.4370
C	97	109.66	130	2.0297	18.1276	8.6375
X+C	90	108.78	129	2.3798	18.9240	8.9963

G:guar; X: xanthan; X+G: xanthan+guar; LBG: locust bean gum; HPMC: hydroxypropylmethylcellulose; C: kappa-carrageenan; and X+C: xanthan+carrageenan.

Table 2 Dielectric constants and dielectric loss factors of gum types in powder form and rice flour.

Hydrocolloid	ε'	ε''
Xanthan gum	2.855	0.202
Guar gum	2.908	0.383
Locust bean gum	2.418	0.279
HPMC	1.728	0.078
Carrageenan	2.951	0.232
Rice flour	3.108	0.491

Table 3 Bulk densities of hydrocolloids in powder form and rice flour.

Hydrocolloids	Bulk density (g/cm^3)
Xanthan	0.862
Guar	0.628
Locust bean	0.620
HPMC	0.460
Carrageenan	0.907
Rice flour	0.810

types in powder forms, it can be seen that HPMC and locust bean gum had the lower bulk density than the other gums. In the study of Ndife et al.,[7] a positive correlation between bulk densities and dielectric properties of starches in granular form was shown.

When dielectric loss factors of cake batters at 25°C were considered (Table 1), like dielectric constant values, xanthan gum, and xanthan-guar gum blend containing cake batters gave the highest values. Dielectric loss factor is the most important parameter that influences the microwave heatability. The higher the dielectric loss factor, the faster will be the heating in microwave oven. Therefore, xanthan gum and xanthan-guar gum blend containing cake batters are expected to heat faster and cause faster gelatinization than other gums. When dielectric loss factor values of powder forms of gums were investigated, the highest value was obtained from guar gum (Table 2).

Gum addition affected gelatinization temperatures of cake batters differently depending on the gum type (Table 1). In the study of Rojas et al.,[15] it was found that hydrocolloids may interact with the starch to produce an increase or decrease of the temperature gelatinization ranges, depending on the hydrocolloid. When gelatinization enthalpies are investigated, it can be seen that addition of gums increased the gelatinization enthalpies of cake formulations, which means more energy will be needed for starch gelatinization (Table 1). The reason for this can be water binding ability of the gum types. There will not be enough water for rice starch for gelatinization in the presence of gums, therefore, more energy will be needed for starch gelatinization. Thus, the gelatinization enthalpy values of gum containing cake formulations were higher than control cakes.

Figures 1 and 2 show the variation of dielectric constant and loss factors of cake batters as a function of temperature. One can observe that in all figures, the values are nearly constant for almost all gum types until temperature of 85°C. Then, there was a sharp increase. This sharp increase in dielectric properties after this temperature could be associated with starch gelatinization. Gelatinized starch binds less water to its structure; therefore, more water is free to respond to the alternating field.[17]

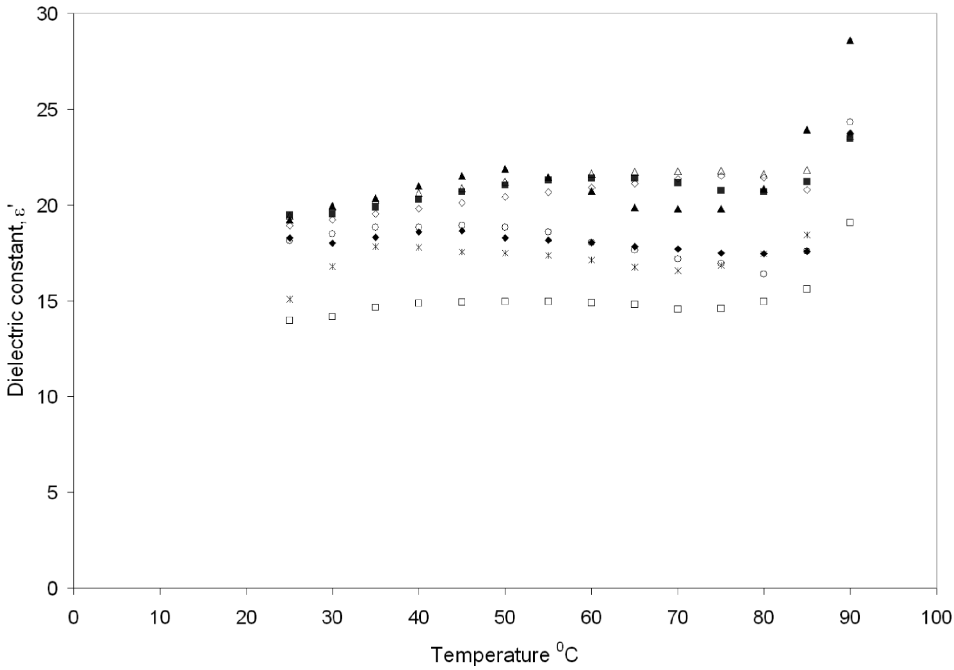

Figure 1 Effect of temperature change on dielectric constant values of gluten-free cake batters (⧫ : control; ■ : xanthan gum; ▲ : guar gum; △ : xanthan - guar gum; □ : locust bean gum; * : HPMC; ◯: carrageenan; and ◇ : xanthan - carrageenan).

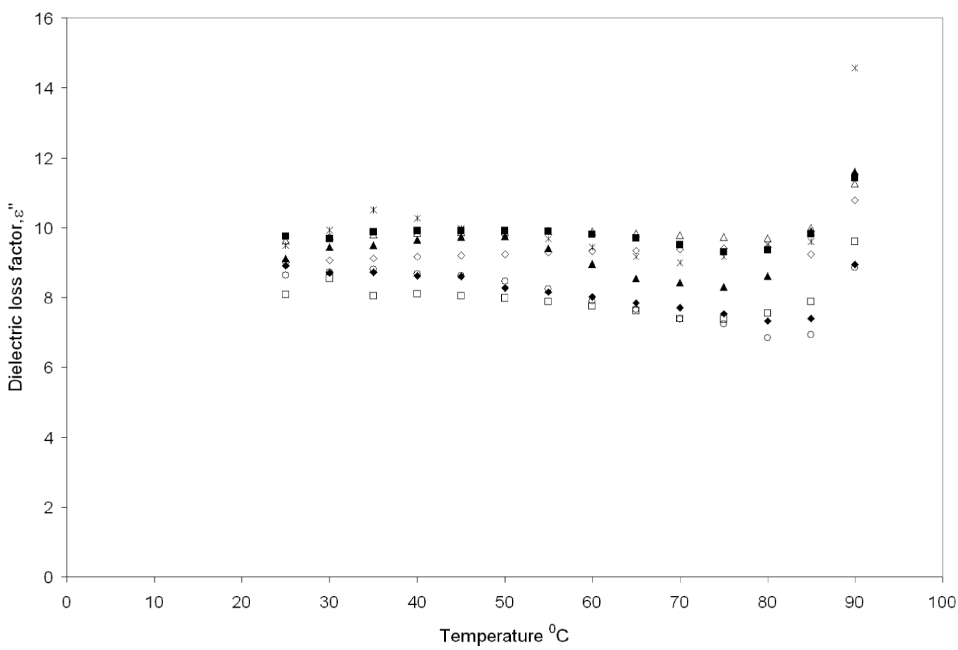

Figure 2 Effect of temperature change on dielectric loss factor values of gluten-free cake batters (⧫ : control; ■ : xanthan gum; ▲ : guar gum; △ : xanthan - guar gum; □ : locust bean gum; * : HPMC; ◯: carrageenan; and ◇ : xanthan - carrageenan).

CONCLUSION

This study showed that addition of different types of hydrocolloids could change the dielectric and thermal properties of rice cake batters. Temperature dependence of dielectric properties of cake batters was significant only after temperature of 85°C, which can be due to gelatinization and significant structure change at this temperature. Addition of gums caused an increase in the gelatinization enthalpy values. Xanthan and guar containing batters had the highest dielectric properties. As long as dielectric properties are concerned, it can be concluded that cake batters containing xanthan and guar gum heat and gelatinize faster in microwave processing. Therefore, usage of these gum types alone or in blended form can be recommended for a gluten-free rice cake batter for baking in microwave or microwave-assisted ovens. Dielectric and thermal properties of rice cake batter will be helpful for modeling of microwave baking of gluten free products and for development of new microwavable gluten free product.

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