Effect of Microwave Irradiation and Conventional Heating on Cookie Quality

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ABSTRACT

An investigation of microwave irradiation was undertaken to determine its effect on cookie quality. Cookie doughs were prepared from wheat flour, eggs, butter, and three kinds of sugars. A part of the prepared cookie dough was irradiated in a microwave oven for 1-5 min and compared with the remaining cookie dough that was baked at 150 ℃ for 2-14 min in a conventional oven. Using fructose, the browning of the cookies developed most rapidly and most strongly. All of the cookies heated by microwave irradiation showed some partial browning in the center of the cookie, whereas those baked by conventional heating showed only surface browning. The amount of 2,3-dihydro-3,5-dihydroxy-6-methyl-4*(H)*-pyran-4-one (DDMP), as an indication of flavor formation, was measured by HPLC in cookies with various sugars and in a model system consisting of fructose and β-alanine. The results showed that microwave irradiation also produced DDMP in cookies, and the DDMP amount in the cookie with fructose was the greatest among those of the three sugars.

INTRODUCTION

Recently, the microwave oven has become widespread in the world since this method of cooking is rapid and convenient. It is used not only for thawing frozen food, but also for food preparation. Microwave irradiation is excellent for heating without losing the natural color of green vegetables. Furthermore, it is well suited for reheating of food. However, this method is said to be inadequate for the formation of favorable browning and the desirable flavor of foods. To resolve these problems, Hsia and Ogasawara (1985) and Hasted et al. (1948) attempted to use food coating compositions containing starches and salts. Nagai (1973a, 1973b) examined a system of Maillard mixtures of lactose with either L-serine or DL-threonine. Other approaches were also reported using the Maillard reaction of D-glucose and L-cysteine (Kaanane and Labuza 1989; Chen et al 1988). This reaction system of D-glucose and L-cysteine has been generally known to be one of the major processes causing browning in thermally treated foods.

We have previously examined the effect of various sugars, such as fructose, glucose and sucrose, on the quality of baked cookies using conventional heating (Nishibori and Kawakishi 1992). Browning appeared the most strongly on the surface of cookies using fructose, and there was greater production of 2,3-dihydro-3,5-dihydroxy-6-methyl-4*(H)*-pyran-4-one (DDMP) in cookies made with fructose. We suggest that the amount of DDMP formed in these cookies may serve as an indicator of flavor formation. Browning and DDMP formation were also confirmed in a model system which used fructose and β-alanine (Nishibori and Kawakishi 1988, 1990). From these results, it was proposed that fructose might promote rapid browning and favorable flavor formation during microwave oven heating.

There have been numerous investigations concerning the role of wheat flour for the baking of cookies and cakes. Several workers (Seguchi and Matsuki 1977, Johnson and Hoseney 1979, Kissell and Yamazaki 1979, Gaines and Donelson 1985) reported that chlorine-treated flours and certain ingredients inhibit gluten formation and improve cookie quality. Nagao et al. (1977), Gaines and Donelson (1985) and Fujii et al. (1990) have shown that the protein content of flour significantly affects the tenderness and vertical expansion of cookies and cakes. Microwave irradiation is a really different heating method from conventional oven heating. It's heating is specific and localized, and food is strongly heated in the center. This special quality might be convenient for drying the center of cookies made with glucose and for the enhancement of cake quality. The present study were designed to investigate browning and the formation of desirable flavor that is due to the microwave irradiation of cookies.

MATERIALS AND METHODS

Materials and Reagents. Commercial wheat flour (15.0% protein, Safeway Inc., Oakland, CA), butter (Challenge Dairy Products Inc., Dublin, CA), fresh eggs and reagent grade sugars (sucrose, D(−)fructose and D(+)glucose) were used for cookie making in this study. β-Alanine was also used for the model reaction with sugars and all of the reagents were purchased from the Sigma Chemical Co. (St. Louis, MO).

Sample Preparation. Three varieties of cookie doughs were prepared from wheat flour (45%), egg (10%), butter (25%) and sugar (20%, one of sucrose, another one of fructose and another one of glucose). The doughs were shaped into cookie form (5.0 x 30 mm in diameter) and heated either in a microwave or conventional electric oven. As a model system for cookies, fructose (180 mg) and β-alanine (89 mg) were placed in test tubes, 27 ml of distilled water were added, and the system heated in the same manner as were the cookie doughs. The amount of added water was 0.01% of the total amount of fructose and β-alanine and the value was calculated from the water content in the cookies. The sample for microwave heating was irradiated at the middle low power setting of 350 W for 1 - 6 min (Quasar Microwave Oven, model MQ 7757 BW), and samples for conventional oven heating were heated at 150 ℃ for 2 - 12 min in a Kenmore conventional oven (Sears, Chicago, IL). These model systems were extracted with 5 ml of distilled water for HPLC analysis. The cookies were extracted with distilled water which was 3 times of the volume of the crashed cookies. Samples for GC/MS analysis was extracted with dichloromethane, and the extract was dried over anhydrouse sodium sulfate for 2 h. The sodium sulfate was then removed by filtration, and the filtrate was concentrated under a stream of dry nitrogen to 0.25 ml.

Capillary Gas Chromatography (GC) / Mass Spectrometry (MS). A Hewlett-Packaed 5792 gas chromatography coupled with a VG analytical ZAB-HS-2F mass spectrometer with a VG 11/250 data system was used for mass spectral identification of components. Operating conditions: ionizing voltage, 70 eV; source temperature, 180 ℃; accelerating voltage, 8000 eV; filament trap current, 100 mA. A 30 m x 0.25 mm (i.d.) fused silica capillary column bonded and cross-linked with DB-1 (film thickness 0.25 mm) was temperature programmed as follows: 70 ℃ for 8 min, 70-180 ℃ at 4 ℃/min, isothermal hold at 180 ℃. Carrier gas velocity was 30 cm/s He.

High Performance Liquid Chromatography (HPLC). HPLC analyses were performed using a Varian Model 5000 Liquid Chromatography. The condition were as reported previously (Nishibori and Kawakishi 1992).

Spectrometric Analysis. The absorbance of the aqueous extracts from the various cookies was measured at 420 nm using a Shimadzu UV-160 Spectrophotometer.

RESULTS AND DISCUSSION

Browning of the Cookies with Various Sugars. The microwave irradiated cookies and the conventionally baked cookies with fructose, glucose and sucrose were extracted with distilled water. Many investigators (Schiffman 1992; Parliment 1992) have indicated that in general, microwave cooking showed that browning proceeds slowly and is not very intense. Absorption, at 420 nm, is generally used as an indication of browning in the Maillard reaction. Aqueous extracts from cookies made with fructose irradiated for more than 5 min in the microwave oven showed the greatest absorption at 420 nm of all of the extracts (Fig. 1). All of the cookies treated by microwaves showed a higher absorption than those baked in a conventional oven. Cookies made with fructose or glucose showed higher absorption than those made with sucrose. Extracts from cookies heated by microwave showed about 2 times, higher absorption than did those extracts from cookies baked in a conventional oven. In the conventional oven, the cookies made with fructose also showed higher absorption than those made with glucose or sucrose. In conventional heating, the absorbance of the extracts increased gradually with heating time. Using the microwave oven, browning appeared to spread from the center outward with heating time. This is not the case for the conventional oven. Here the center of cookies didn't

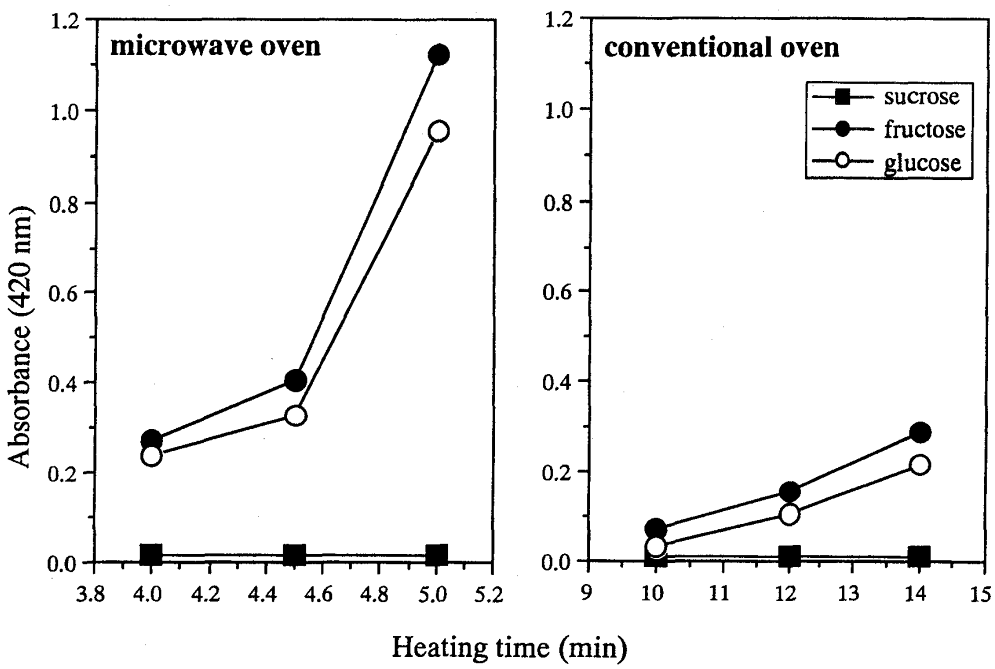

Fig.1 Color formation in cookies with various sugars irradiated at the middle low power setting of 350 W for 4-5 min by microwave oven and baked at 150 °C for 10-14 min by conventional oven.

appear to brown as strongly as the browning at the surface. These results showed that heating by microwave oven promoted browning of the cookies, but the browning proceeds strongly in the center of cookies and appeared relatively slowly on the surface of cookies.

Browning in the Model Reaction of Fructose and β-Alanine. Fig. 2 shows absorption of the extracts at 420 nm in a model system consisting of fructose and β-alanine. Extracts from this model system that were heated by conventional oven showed slightly lower absorption than did those heated in the microwave oven. Irradiation by microwaves appear to accelerate the browning reaction of fructose and β-alanine as compared to that conducted using a conventional oven.

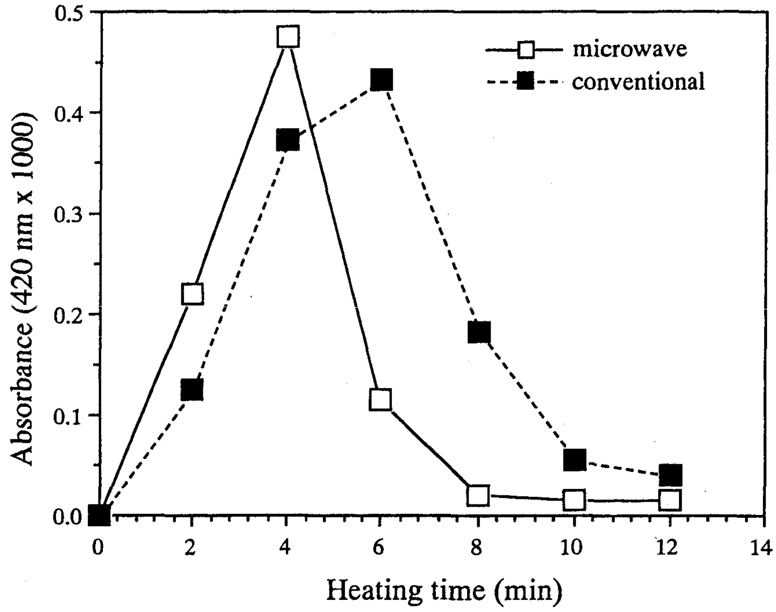

Fig.2 Color reaction of fructose and β-alanine irradiated at the middle low power setting of 350 W for 2-12 min by microwave oven and baked at 150 °C for 2-12 min by conventional oven.

Flavor of the Cookies. A typical gas chromatogram from the model system reaction mixture is shown in Fig. 3. The main compound isolated from the reaction mixture was DDMP. In previous studies (Nishibori and Kawakishi 1988,1990,1992) using HPLC, these authors reported that DDMP was isolated and identified from the reaction products of fructose heated with β-alanine and from cookies baked with various sugars using conventional heating. Parliment (1992) also identified the compound from the reaction of proline and glucose heated by conventional and microwave ovens. He reported that a large amount of DDMP was present in both systems, and the amount in the microwave system was much larger than that in the conventional system. This compound has been found in coffee aroma compounds (Gianturco et al. 1963). It also gives a burnt aroma, described as intense and quinone-like by Harries (1902). And some researchers (Severin and Seilmeier 1968; Jurch 1970) reported that this compound had a caramel-like aroma. But this DDMP was judged odorless at room temperature by Shaw et al (1968). Recently we reported that DDMP had a sweet aroma when it was prepared in a highly purified form (Nishibori and Kawakishi, 1991). The odor threshold value of DDMP is very high, so that it can be assumed that DDMP is odorless. Since a large amount of DDMP was detected in this study, it is suggested that DDMP is an important intermediary substance in the Maillard reaction. Maltol which has a sweet and cookie-like aroma was not detected in this study by GC and HPLC.

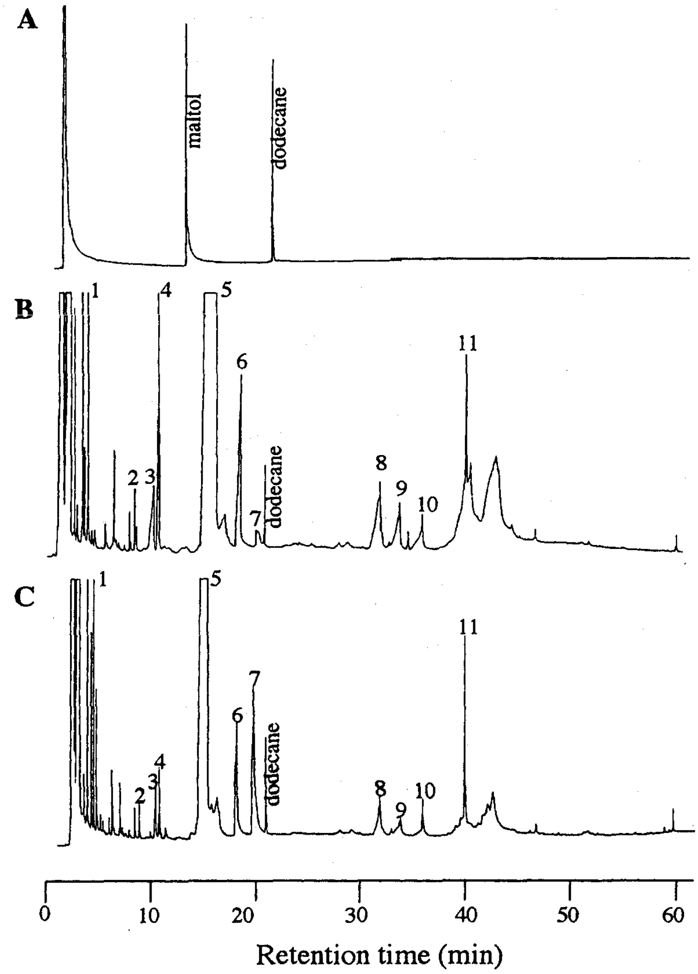

Fig.3 Gas chromatogram of model system extract. GC column; a 30 m x 0.25 mm (i.d.) fused silica capillary column bonded and cross-linked with DB-1(film thickness 0.25 mm); temperature program, 70 °C for 8 min, 50-180 °C at 4 °C/min, isothermal hold at 180 °C.
P1, 2-hydroxymethylfuran ; P2, 2-acetyl-3-hydroxy-4,5-dihydrofuran (isomaltol); P3, 2,5-dimethyl-4-hydroxy-3(2H)-furanone; P4, 2,3-dihydro-3-hydroxy-6-methyl-4(H)-pyran-4-one; P5, 2,3-dihydro-3,5-dihydroxy-6-methyl-4(H)- pyran-4-one (DDMP); P6, 2,3-dihydro-3-hydroxy-6-formyl-4(H)- pyran-4-one; P7, 4-hydroxy-2-acetyl-3(2H)-furanone; P8, 3-(N-(2-formylpyrrolyl))-propionic acid; P9, 3-(N-(2-acetylpyrrolyl))- propionic acid; P10, 3-(N-(2-formyl-5-methylpyrrolyl))- propionic acid; P11, 3-(N-(2-formyl-5-hydroxymethylpyrrolyl))- propionic acid.

Formation of DDMP in Cookies with Various Sugars. DDMP content in the cookies heated by the microwave oven and conventional oven is shown in Fig. 4. In all of the cookies, the longer the heating time, the more DDMP was formed. For both heating systems, cookies made with fructose produced the greatest amount of DDMP. This phenomenon was similar to that observed with the browning of the cookies. DDMP concentration was approximately twice as great in microwave heated cookies as compared to those baked in the conventional oven. The amount of DDMP produced using glucose instead of fructose is significantly less (Fig. 4). The amount of DDMP produced from sucrose is very small compared to the other two sugars.

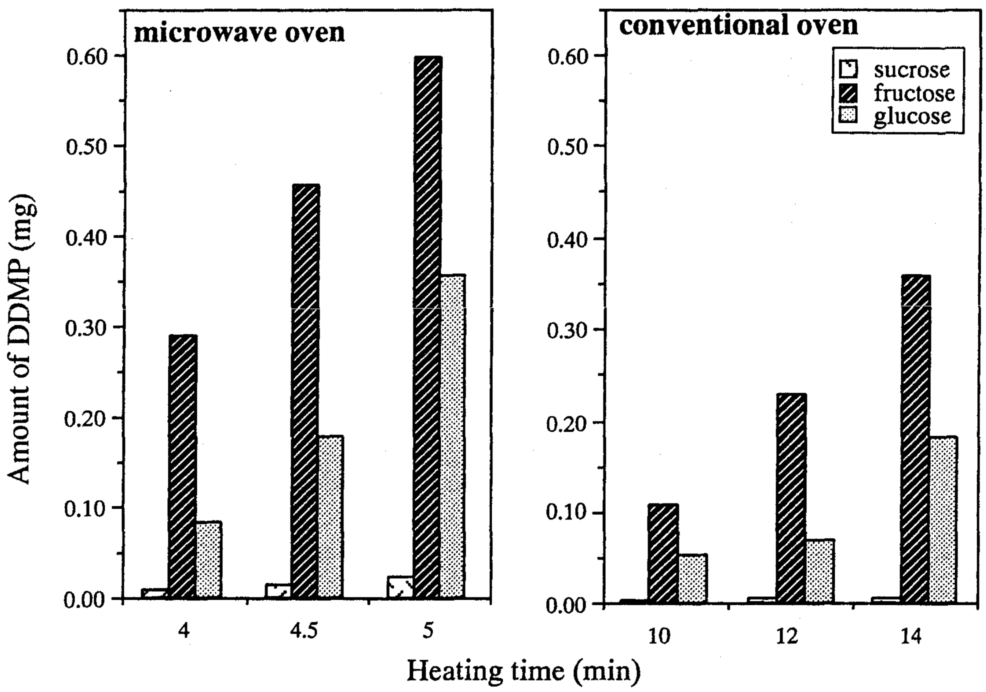

Fig.4 DDMP content in cookies irradiated at the middle low power setting of 350 W for 4.0-5.0 min by microwave oven and baked at 150 °C for 10-14 min by conventional oven.

Formation of DDMP in the Model Reaction. DDMP was produced not only in the baking of the cookies, but also in the model Maillard reaction which used only fructose and β-alanine. The amount of DDMP increased rapidly in the early stages of the reaction in the microwave oven (Fig. 5). Then the amount decreased quite suddenly. In this model system with the conventional oven, DDMP increased up to 4 min, and then rapidly decreased. Therefore, the conventional oven produced the most DDMP. The amount of DDMP at two minutes produced in the microwave oven was similar in amount to the DDMP produced in four minutes by conventional heating. DDMP formation did not follow the rate of browning directly, for browning appears to be slower than does DDMP formation.

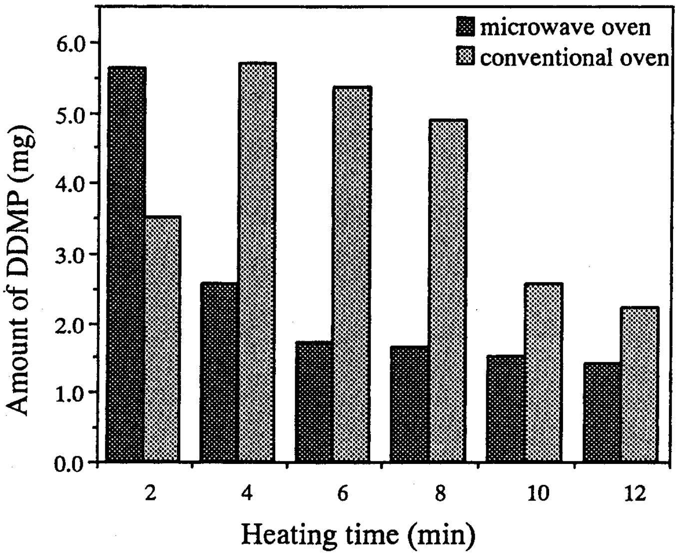

Fig.5 DDMP content in the mixture of fructose and β-alanine irradiated at the middle low power setting of 350 W for 1-6 min by microwave oven and baked at 150 °C for 2-12 min by conventional oven.

It has been generally acknowledged that food barely develops any browning and little aroma during microwave cooking. The result of this study shows that browning on the surface of cookies appeared rapidly using microwave heating, when fructose was used to make the cookies. Since DDMP formation does not appear to parallel browning using the microwave oven, flavor formation due to DDMP production proceeds more rapidly than does browning.

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