

Influence of microwave and conventional cooking on beef liver lipids

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RESUMEN

Influencia de la cocción convencional y en microonda sobre los lípidos de hígado de vaca.

Rodajas de hígado fueron cocinadas con una mezcla de aceite de semilla de algodón y margarina usando horno microonda y cocina de gas. Se determinaron los índices de acidez, índices de peróxido, esteroides totales y perfiles de ácidos grasos de las rodajas de hígado no calentadas y de las cocinadas convencionalmente y por microondas. El tiempo requerido para la cocción de las rodajas de hígado por microondas fue una vez y media el necesitado por el sistema convencional. La mezcla de lípidos calentada por ambos métodos sufrió una disminución significativa en el índice de acidez. Por el contrario, los lípidos extraídos de las rodajas de hígado cocinado mostraron índices de acidez significativamente elevados, aumentados por el proceso de calentamiento.

Los índices de peróxidos de los lípidos calentados convencionalmente fueron siempre más bajos que los obtenidos por microondas, llegando a ser aproximadamente la mitad en el caso de los lípidos extraídos de las rodajas de hígado. Los procesos de cocción redujeron significativamente los niveles de esteroides para todos los lípidos en estudio. El análisis de los ácidos grasos de los lípidos sometidos a tratamientos por calor demostró la existencia de degradación oxidativa y producción de ácidos de cadena corta.

PALABRAS-CLAVE: Cocción convencional – Cocción en microonda – Hígado (vaca) – Lípido.

SUMMARY

Influence of microwave and conventional cooking on beef liver lipids.

Liver slices were cooked with a mixture of cottonseed oil and margarine using microwave oven and gas cooker. The acid values, peroxide numbers, total sterols and fatty acid profiles of unheated and cooked liver slices conventionally and by microwaves were determined. The time required for cooking liver slices by microwaves was one-half of the time required conventionally. Heating the lipid mixture by both heating methods caused highly significant decrease in the acid value. Conversely, the acid values of lipids extracted from cooked liver slices were highly significantly increased by the heating processes.

The peroxide values of the lipids conventionally heated were always lower than those obtained by microwaves. The peroxide value of microwavable liver lipids was nearly twice as high as that produced by conventional heating. Heating processes significantly reduced the sterol levels for all lipids under study. The fatty acid analysis of the lipids under heat treatments demonstrate the occurrence of oxidative degradation and production of short-chain acids.

KEY-WORDS: Conventional cooking – Lipid – Liver (beef) – Microwave cooking.

1. INTRODUCTION

There are two basic processes for food cooking, i.e., cooking by gas cooker and microwave ovens. Nowadays cooking by microwaves is the most versatile method all over the world. It is more energy efficient and reduces the cooking time as compared with conventional heating (1). The user of the appliance prefers the microwave cooking procedure which is characterized by speed and saves the cooking time compared to other classical cooking methods. Recently, several publications reported the deleterious effects of cooking by microwaves. For instance, it has been reported that vitamins are adversely affected by microwave cooking (2). Reheating food in microwave ovens in cook chill food service systems has been shown to cause loss of nutrients (3) (4) (5). Microwave cooking resulted in significantly greater losses of several amino acids of Colossus peas than conventional heat treatment (6). Foods prepared by using a microwave oven usually generate less desirable flavours and browning than those prepared by a conventional oven (7). It has been found that the amount of volatiles obtained from microwave-boiled beef was one-third that of beef prepared conventionally (8). In another study, microwave-prepared beef samples were weaker in flavour and less pleasant than samples prepared by conventional methods (9).

From the above consideration and the wide spread use of microwave ovens for food cooking, our main interest was focused on designing food system consisting of liver slices cooked by a mixture of cottonseed oil and margarine in order to display the effect of microwave heating on the lipids of liver slices. The following parameters were determined: acid value, peroxide value, total sterols and fatty acid profile of liver lipids heated by microwaves. Conventional heating was conducted simultaneously with the microwave heating. Therefore, a comparison can easily be made between the two cooking methods on some chemical constituents of liver lipids. Changes in the cottonseed oil and margarine mixture used for cooking liver slices heated conventionally and by microwaves were also studied.

2. MATERIALS AND METHODS

2.1. Source of beef liver

Fresh beef liver sample was obtained from the main slaughter house of Cairo, 2 hours after slaughtering. Liver was washed and divided into three equal portions (ca 1 kg each) and sliced. The weight and dimension of each liver slices were nearly 60 g and 8x4x1 cm (length x width x thickness), respectively.

2.2. Cooking lipids

A mixture of cottonseed oil and margarine (1:1, w/w) was used for cooking liver slices.

2.3. Thermal heating

The microwave oven used for liver cooking was a Moulinex electronic type 823 (France). The frequency of the radiation emitted in this oven was 60 Hz and when operated at full power it provided ca 1300 W. Suitable amounts of cooking lipids (250 g) and liver slices (250 g) were heated using a Moulinex glass tray (26 cm diameter and 3 cm depth) and placed on a turn table and drive which slowly rotated the food materials to ensure a uniform heating. The prepared liver samples were heated by microwave oven using the high power level for 8 min (4 min for each side).

A comparative pan-fat frying or conventional liver cooking using a 137-4 LP main May flower four gas cooker (Main gas appliance Ltd., England) was conducted for 16 min. A non-stick pan fryer of 26 cm diameter and 3 cm depth was used for cooking liver slices. The internal temperatures of the lipid mixture heated conventionally and by microwaves were $230\pm 2^\circ\text{C}$ and $205\pm 2^\circ\text{C}$, respectively. These values were recorded by inserting a calibrated glass thermometer into the lipid mixture immediately after the completion of the cooking.

2.4. Lipid extraction

The lipids were extracted from the cooked and uncooked liver samples using chloroform: methanol mixture (2:1, v/v) as outlined by Kates (10).

2.5. Lipid analysis

Unheated and heated lipid mixture as well as the lipid extracted from fresh and cooked liver slices either heated conventionally, or by microwaves were analyzed for the acid value, peroxide number, total sterol content and fatty acid composition. All these determinations were conducted in triplicates and the results are presented as mean value in the text.

2.6. Acid value

A known weight of lipids (ca 2 g) was dissolved in neutralized alcohol (25 ml) and titrated with potassium hydroxide (0,1 N) (AOCS 11).

2.7. Peroxide number

A known weight of lipids (ca 2 g) was dissolved in a mixture of acetic acid: chloroform (3:2, v/v), then saturat-

ed solution of potassium iodide (1 ml) was added. After exactly 1 min., the liberated iodine was titrated with sodium thiosulfate solution (0,1 N) in the presence of starch solution (0,5 ml, 1%) as an indicator (AOCS 11).

2.8. Total sterol content

A known weight (ca 2 g) of lipids was dissolved in chloroform and the volume was completed to 100 ml with the solvent. An aliquot from the chloroform extract (2 ml) was thoroughly mixed with the colour reagent (acetic anhydride - sulfuric acid mixture, 30:1, v/v). The absorbance was recorded at 680 nm as outlined by Plummer (12). A standard cholesterol curve at the range of 0,1-1 mg was used for the estimation of the total sterol content of the samples under study.

2.9. Preparation and methylation of fatty acids

Lipid samples were saponified with potassium hydroxide solution (20%, w/v) overnight. The unsaponifiables were extracted three times with diethyl ether, and the ether extract was discarded. The remaining soap solution was acidified with sulfuric acid (20%, v/v) and the liberated fatty acids were extracted three times with ether.

The combined ether extract was washed several times with distilled water and dried over anhydrous sodium sulfate. The fatty acids were methylated with diazomethane ethereal solution, the solvent was removed and the residue was dissolved in chloroform. An aliquots from this solution were injected into gas-liquid chromatograph.

2.10. Identification and quantitative determination of fatty acids

The fatty acid methyl esters were analyzed by a GCV Pye Unicam gas chromatograph equipped with dual flame ionization detectors. The chromatograph was fitted with a coiled glass column (1,5 m x 4 mm) packed with Chromosorb R (100-120 mesh, WAN) and coated with 3% SP-2310/2% SP-2300 (Cyano silicone). The oven temperature was programmed at 6 C/min from 120 C to 250 C then isothermally at 250 C for 15 min. Detector and injector temperatures were 220 C and 300 C, respectively. Gas flow rates for N₂, H₂, air were 30, 33, 330 ml/min., respectively. Comparison of the retention times of fatty acid samples with retention times of standard compounds aided in the direct identification of the peaks. The percentage composition for each component of the fatty acid mixture was calculated by the compensated normalization method using the PU 4810 computing integrator (Philips).

2.11. Statistical Analysis

The effect of conventional and microwave cooking processes on the acid value, peroxide number, total sterols and fatty acid pattern of the tested food lipids were statistically analyzed (F-test) using the microcomputer statistical package "Statgraphics" Statistical system (version 2.6 serial number 1357673 copyright USA), Statistical Graphics Corporation.

3. RESULTS AND DISCUSSION

In the present study, an equal amounts of beef liver slices (0,5 kg) were cooked using a mixture of cottonseed oil and margarine by conventional and microwave heating processes. The cooking time was 16 min and 8 min, respectively. This means that microwave cooking procedure was twice as fast as that cooked by conventional heating. Hence, microwave heating is more energy efficient and reduces cooking time in comparison with the conventional heating. Similar results were also found by Farag et al (13) who reported that butter conversion to samn or ghee was accomplished in one-half of the time required by conventional heating, since microwave heating reduces the cooking time in comparison with the conventional heating. One would indicate that the microwave action differs from conventional cooking in that microwave cooking takes place within the food and not initially on the surface. The acceleration of food cooking due to microwaves may be interpreted as follows. Most foods have a high proportion of water which in turn attracts the microwaves. There is rapid vibration as these water molecules change direction towards the microwaves at a rate about 2,5 billion times per second in a domestic oven. Thus, the water molecules become very excited and the friction occurring causes a considerable and rapid buildup of heat in the food itself (14). Consequently, one would conclude that the heating temperature and the mode of heating are together responsible for reducing the

cooking time of foods.

Changes in the acid value of a mixture of cottonseed oil and margarine (1:1, w/w) heated conventionally (deep-fat frying) and by microwaves are shown in Table I. Heating the lipid mixture by both heating processes caused highly significant ($P < 0,01$) decrease in the acid value compared to the unheated lipid mixture. The acid values of the lipids remained after cooking liver slices (fried lipid mixture) were highly significantly increased in comparison with the control lipids. However, no significant change was found in the acid value of the fried lipid mixture due to the two heating methods. It is worth mentioning that the levels of the acid values of the fried lipid mixture were approximately twice as high as that of the heated ones.

The acid values of lipids extracted from cooked liver slices produced conventionally and cooked by microwaves were highly significantly ($P < 0,01$) increased by the heating processes. However, there was no significant difference between the acid values of lipid liver cooked by two heating methods. Generally speaking, the acid values of the lipid liver were much higher than those of fried lipid mixture conventionally heated or by microwaves. The liberation of small amounts of fatty acids from their triglycerides might be due to the influence of heat and the high water content in the liver slices. Similar findings were reported by Perkins (15).

The peroxide values for the fried lipid mixture heated conventionally and by microwaves as well as fresh and

Table I
Acid Value, Peroxide Number and Total Sterols (g%) of Lipid Mixture, Fried lipid Mixture and Liver lipids Cooked Conventionally and by Microwaves.

Heating method	Acid value	Peroxide number	Total sterols
Lipid Mixture			
Unheated (fresh)	0,19 a	1,96 a	0,209 a
Conventional heating	0,12 b	3,13 b	0,181 b
Microwave heating	0,15 c	4,87 c	0,202 a
Fried Lipid Mixture			
Unheated (fresh)	0,19 a	1,96 a	0,209 a
Conventional cooking	0,39 b	4,40 b	0,189 b
Microwave cooking	0,33 b	5,28 c	0,195 b
Liver Lipids			
Unheated (fresh)	1,08 a	3,80 a	2,508 a
Conventional cooking	1,85 b	5,90 b	1,589 b
Microwave cooking	1,76 b	10,90 c	1,997 b

Lipid mixture consists of cottonseed oil and margarine (1:1, w/w).

Fried lipid mixture indicates the lipid mixture remained after cooking liver slices.

Liver lipids refer to the lipids extracted from liver slices cooked conventionally and by microwaves.

Acid value is expressed as milligrams of KOH required to neutralize 1 g lipids.

Peroxide number is expressed as milliequivalents peroxide per Kg lipid.

Numbers in the same column for each heat treatment followed by the same letter are not significantly different.

lipids extracted from liver slices are presented in Table I. In general, heating processes caused highly significant increase ($P < 0,01$) in the peroxide value. In addition, the peroxide values of the lipids conventionally heated were always lower than those obtained from microwave heated lipids for all treatments. The most worse results were obtained from the lipids extracted from microwavable liver slices, since its peroxide value was nearly twice as high as that of lipids from cooked liver slices produced by conventional heating. The acceleration of lipid oxidation due to microwaves may be interpreted as follows. It has been reported that reactive free radicals might be formed by exposure to microwave energy (16) and various chemical reactions are said to be induced by microwave energy (5) (15). The first step of lipid peroxidation is the abstraction of a hydrogen atom from the active methylene group (adjacent to double bonds) to form free radical (17). This reaction can be accelerated by the addition of a radical source, by irradiation, or by raising the temperature. As already mentioned microwave is energy efficient to produce free radicals which in turn rapidly react with the atmospheric oxygen and produce hydroperoxides. The proposed mechanism for the hydroperoxide formation by microwave heating is similar to the reaction sequence of lipid oxidation (17) (18).

Our data suggest that the microwave heating can be applied in certain cases such as mold inhibitors (19). However, this cooking method has to be forbidden in cooking foods containing labile chemical structures such as lipids and vitamins.

The total sterols of fresh and heated lipid mixture conventionally and by microwaves are shown in Table I. Generally speaking, heating processes significantly ($P < 0,01$) reduced the sterol levels for all heat treatments. It is worth mentioning that the sterol contents for all lipids in all cases due to conventional heating were lower than that heated by microwaves. During frying, the heating medium may experience abusive conditions due to repeated exposure to oxygen at elevated temperature and these conditions might be responsible for the reduction of

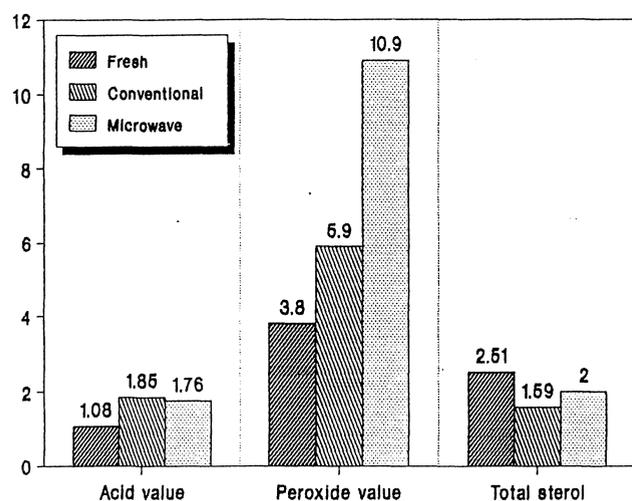


Figure 1
Acid value, peroxide value and total sterols (g%) of lipids obtained from liver slices cooked conventionally and by microwaves.

sterol content. In this respect, Ghavami and Morton (20) indicated that both hydrogenated and deodorized soybean oil when heated in two identical compartments of the deep-fat fryer, at $180^{\circ}\text{C} \pm 10$ for an extended period lost considerable quantities of the total sterols originally present. Also, Park and Paul (21) found that the disappearance of cholesterol of tallow heated at 190°C proceeded faster than at 155°C . Fig. 1 presents the levels of acid value, peroxide number and total sterols of lipids obtained from fresh liver slices and the ones cooked conventionally and by microwaves.

Fatty acid composition of microwave and conventionally heated lipid mixture

Table II shows the fatty acid profiles of lipid mixture heated conventionally and by microwaves. The fatty acid levels were divided into three classes, i.e., trace ($< 1\%$), minor ($> 1-10\%$) and major ($> 10\%$) components. The fatty acid patterns of cottonseed oil and margarine mixture (control) indicated that the fatty acids: 8:0, 10:0, 12:0, 14:0, 18:0 and 16:0, 18:1, 18:2 occurred as minor and major substances, respectively. The fatty acid profiles of fried-lipid mixture remained after cooking liver slices by the two heating methods indicate the disappearance and decrease the levels of short and medium chain fatty acids, respectively.

Table II
Fatty Acid Composition (%) of Fresh and Fried Lipid Mixture

Fatty acid	Fresh	Conventional heating	Microwave heating
8:0	1,46 a	0,00 b	0,32 c
10:0	1,24 a	0,00 b	0,36 c
12:0	1,28 a	0,00 b	1,06 c
14:0	4,51 a	3,38 b	4,15 a
16:0	18,76 a	20,12 a	18,25 a
18:0	6,85 a	7,78 a	7,70 a
18:1	30,17 a	31,08 a	31,27 a
18:2	35,74 a	37,65 b	36,89 a

Numbers in the same row followed by the same letter are not significantly.

Fatty acid composition of microwave and conventionally heated beef liver

Table III illustrates the fatty acid composition of beef liver slices cooked by microwave oven and conventional gas cooker. The lipids of fresh liver slices (control) was characterized by having myristic (14:0) as trace component and palmitic (16:0), margaric (17:0), stearic (18:0), oleic (18:1), linoleic (18:2), arachidic (20:0) acids as major substances. The C18 fatty acids represented more than 58% of the total fatty acids.

The fatty acid profiles of the lipids extracted from liver slices heated by the two heating processes demonstrated the appearance of short and medium chain fatty acids, a

Table III
Fatty Acid Composition (%) of Lipids Extracted From
Fresh and Cooked Beef Liver Slices

Fatty acid	Fresh	Conventional cooking	Microwave cooking
6:0	0,00 a	1,10 b	0,46 c
8:0	0,00 a	0,74 b	0,35 c
10:0	0,00 a	4,13 b	0,00 a
12:0	0,00 a	1,49 b	0,45 c
14:0	1,20 a	3,39 b	1,88 c
14:1	0,00 a	2,53 b	0,00 a
15:0	0,00 a	1,50 b	0,00 a
16:0	10,92 a	17,42 b	18,77 b
17:0	11,77 a	1,71 b	0,55 c
18:0	32,10 a	16,89 b	33,92 a
18:1	11,67 a	16,65 b	19,11 c
18:2	14,73 a	23,64 b	24,39 b
20:0	17,61 a	8,81 b	0,12 c

Numbers in the same row followed by the same letter are not significantly different.

significant ($P < 0,05$) decrease of 17:0 and 20:0 levels and a significant ($P < 0,05$) increase of 16:0 content. The total levels of C18 acids for the control and conventionally heated liver lipids were nearly the same whilst the proportion of each acid belongs to C18 was quite different. One might suggest that the reduced percentages of 20:0 and 17:0 acids for conventionally heated liver lipids led to an increase in the level of 16:0 and the appearance of short and medium chain fatty acids.

Cooking liver slices by microwaves caused no change in 18:0 content, highly significant increase ($P < 0,01$) in the levels of 18:1, 18:2 and 16:0 acids at the expense of 20:0 and 17:0 acids. The increase and decrease the levels of certain fatty acids due to microwaves may be interpreted as follows. The heating processes may have caused an abstraction of a hydrogen atom from the active methylene group adjacent to the carboxyl groups to produce free radicals followed by oxidation degradation at α - β positions to produce short chain fatty acids. This reaction is similar to that described by Varrentrapp (17). This reaction leads to an increase in the acid value. The aforementioned mechanism is postulated since gas-liquid chromatographic analysis of fatty acids show an increase in 16:0 level, appearance of short and medium chain fatty acids and decrease in 20:0 content.

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