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Influence of microwave irradiation on lipid oxidation and acceptance in peanut (*Arachis hypogaea* L.) seeds

*Jittrepotch, N., Kongbangkerd, T. and Rojsuntornkitti, K.

Department of Agro-Industry, Faculty of Agriculture, Natural Resources and Environment, Naresuan University, Phitsanulok, 65000, Thailand

Abstract: The purpose of this study was to evaluate the occurrence of lipid oxidation in peanut (Arachis hypogaea L) seeds which were heated by microwave irradiation. Peanut seeds were exposed to microwaves for 0, 2.5, 3.5, 4.5, 5.5 and 6.5 min at frequency of 2,450 MHz, 450 watts microwave oven. The quality characteristics of peanut seed (moisture content and color values), extracted peanut oils (PV, TBA, p-anisidine, FFA) and acceptance test were analyzed. Moisture contents and color values (L*) of seeds significantly decreased ($P < 0.05$), whereas a* and b* values increased ($P < 0.05$) from 0 – 6.5 min of heating time. The PV, p-anisidine and FFA of the extracted oils significantly increased ($P < 0.05$) whereas TBA values were not significantly ($P > 0.05$). Lower acceptance in all attributes was observed in the samples heated at 6.5 min, than in other samples. The results indicated that microwave irradiation on peanut seeds contributed to lipid oxidation and acceptability.

Keywords: microwave irradiation, lipid oxidation, peanut seeds, acceptance

Introduction

Microwave heating is a modern and widely used method for food preparation. Microwaves refer to the electromagnetic waves in the frequency range of 300 to 300,000 MHz. Electromagnetic waves are of electrical and magnetic energy moving together through space. They include gamma rays, x-rays, ultraviolet radiation, visible light, infrared radiation, microwaves and the less energetic radio waves. Microwaves can pass through materials like glass, paper, plastic and ceramic, and be absorbed by food and water but they are reflected by metals (Mullin, 1995). Microwave ovens are present in the majority of homes and today more people use microwave ovens for cooking and reheating than ever before. Nowadays convenience foods that have been subjected to minimal processing are flooding the market (Yoshida *et al*., 2001; Yoshida *et al*., 2002). Although, there is sufficient information available on the consequences of microwave heating on the composition and nutritional quality of food, there has been speculation on the ease of free radical formation when fatty foods are exposed to microwave energy. The differential heating behavior of food components can result in severely uneven heating of certain foods rich in fats and proteins. Numerous investigations have been done to study the effects of microwave on food constituents and various chemical reactions are induced by microwave energy (Finot, 1995). For seed industry, microwave energy applications that have been studied for potential use in agriculture including are product drying, seed treatments for stimulation of germination, stored-product insect control, product processing to improve nutritional value or improve quality retention in storage, and sensing of product moisture content (Nelson, 1987).

Peanuts are grown widely and especially in India, China, and the United States of American. A lot of peanuts may be consumed raw, roasted, pureed, or in a variety of the other processed forms, and constitute as a multi-million-dollar crop world wide (Yu *et al*., 2005) with numerous potential dietary benefit. Raw peanut can be stored without lipid oxidation for over one year if they remain whole and intact. However, if the peanut are ground, they undergo flavor deterioration readily due to enzyme activation. On the other hand, if the peanut are dry-roasted to inactivate enzyme, they are oxidatively stable (Frankel, 2005).

Recently several peanut cultivars were developed with elevated concentrations of the monounsaturated

Corresponding author.
Email: *nitipongj@nu.ac.th*
Tel: +66-55-261000 ext. 2747, Fax: +66-55-261987

fatty acid i.e. oleic acid, in relation to the other highly oxidizable polyunsaturated fatty acids (Reed *et al*., 2002). Its major acids are 8-14% palmitic, 36-67% oleic and 14-44% linoleic along with 5-8% (total) of C:20, C:22, and C:24 saturated and monoene acid (Frank, 2005).

Lipid oxidation is the major form of deterioration in foods, even when the lipid content is very small. Quality problems due to lipid oxidation are in fact aggravated in low-fat foods, where oxidation decomposition products are more readily volatilized and perceived and have a greater impact on off-flavor (Frankel, 2005). Lipid components of animal fats and vegetable oils microwave heated were also investigated (Yoshida *et al*., 1990; Farag, 1994). Some works indicated that peroxide value of microwave heated oils increased with increase of microwave increasing time (Ruiz-Lopez *et al*., 1995). It was found that the rate of quality deterioration, such as oxidation, depends on the polyunsaturated fatty acid content (Yoshida *et al*., 1990; Lin *et al*., 1999). However, little information is available about the influence of microwave irradiation on lipid oxidation and the acceptance of microwave peanuts.

Therefore, the current objective was to study the influence of microwave irradiation on lipid oxidation and the acceptance of microwave peanuts as affected by time. The quality characteristics of peanut seed (moisture content and color values), extracted peanut oils (POV, TBA, *p*-anisidine, FFA) and acceptance test were analyzed.

Materials and Methods

Chemicals reagents

2-thiobarbituric acid was purchased from Sigma (St Louis, Mo, USA). *p*-Anisidine was purchased from Fluka (Buchs, Switzerland). Analytical-grade solvents were obtained from Merck (Darmstadt, Germany).

Materials

Peanut (*Arachis hypogaea* L.) seeds were purchased from supermarket in Phitsanulok, Thailand. Each seed typically weighted 0.72 ± 0.13 g. The seeds were stored in polyethylene bags at the room temperature (38 ± 2°C) until analysis.

Sample preparation

Peanut seeds were placed in Pyrex Petri dishes 9.5 cm diameter (50 seeds in each Petri dish). A microwave oven is Sharp, Model RA468, 900 watts, 2,450 MHz frequencies (50 % power setting). Peanut seeds were heated for 0, 2.5, 3.5, 4.5, 5.5 and 6.5 min. After being heated, peanut seeds were allowed to cool to ambient temperature and thoroughly mixed prior to oil extraction.

Moisture analyses

The moisture contents of samples were determined by weighing and drying at 105ºC according to the Official Method of Analysis of Official Analytical Chemistry (AOAC, 1995).

Lipid extraction

Total lipids were extracted from peanut seeds by Folch procedure (1957).

Peroxide value measurement

Peroxide value (PV) of the extracted lipids was determined following a procedure of Buege and Aust (1978) and expressed as meq/kg lipid.

TBA measurement

The thiobarbituric acid (TBA) value was measured according to the Official Methods and Recommended Practices of the American Oil Chemists' Society (AOCS, 1989).

Free Fatty acids measurement

Free fatty acid (FFA) were measured according to the Official Methods and Recommended Practices of the American Oil Chemists' Society (AOCS, 1989). FFA were calculated as oleic acid and expressed as percent of peanut seeds.

p-anisidine value measurement

The *p*-anisidine value (AnV) was measured according to the Official Methods and Recommended Practices of the American Oil Chemists' Society (AOCS, 1989).

Color value measurement

After heating in microwave oven, the red skins were removed by hand and thoroughly mixed prior to color value measurement. The color of samples measured in the L^* a^* b^* mode of CIE (angle 10°, illuminant D65) using a Hunter Lab (DP 9000, Hunter Associates Laboratory, Reston, VA, USA). L^*, a^*, b^* indicate lightness, redness/greenness, and yellowness/blueness, respectively.

Acceptability test

Microwave peanut seed samples were evaluated for acceptance by 50 untrained panels. The panelists were under graduated students and housewives in the Faculty of Agriculture, Natural Resources and Environment, Naresuan University between the age of 20 and 55 years. A nine-point hedonic scale, in which a score of 1 = dislike extremely, 5 = neither like nor dislike and 9 = like extremely, was used for evaluation (Meilgaard *et al*., 1990). Individual samples of each treatment were placed on dishes (diameter 3.0 cm). A balanced incomplete block (BIB) design was used to group samples (Meilgaard *et al*., 1990). Each of thirty panelists was randomly assigned on block of five samples the design. Samples were randomly selected and coded with three-digit random numbers and presented to the panelists at room temperature. During evaluation, the panelists were situated in private booths. Room temperature water was given to rinse the month between samples. The panelists evaluated each sample for appearance, color, odor, texture and overall liking.

Statistical analysis

Microsoft Excel 5.0 (Microsoft Co., Washington, USA) was used for all statistical analyses. Data were analyzed using one-way ANOVA, and means were compared using Duncan's multiple range test. Differences were considered to be significant at $P<0.05$. All the experiments were done in duplicate.

Results and Discussion

Changes in moisture contents

Microwave treatment for increasing periods gradually reduced the moisture contents (Figure1). The peanut moisture contents decreased significantly ($P<0.05$) with microwave heating times and ranged between 8.56% - 1.58%. The moisture content of the untreated microwave of peanut seeds was 0.86 %. Peanut seeds were treated for 6.5 min had significantly lower final moisture content than other treatments. This decrease indicates that the peanut seeds have been heated to boiling temperature of water, causing evaporation to take place. The sample treated for more than 4.5 min had the aroma and the color for roasted beans.

Changes in peroxide values

The changes of the PV during microwave heating are shown in Figure 2. The PV of the peanuts increased significantly ($P<0.05$) with the increase in the period of microwave heating times. PV of samples were 2.31 – 7.55 meq/kg lipid. The peroxide value is a measure of the content of hydroperoxides, which are primary oxidation products. This results from rapid decomposition of hydroperoxides to secondary oxidation products at elevated temperature. They are extremely unstable and decompose *via* fission, dehydration, and formation of free radicals to yield a variety of chemical products, such as alcohols, aldehydes, ketones, acids, dimmers, trimers, polymers, and cyclic compound (Tan *et al.,* 2001). Peanuts are characterized by high oil and protein contents and low percentage of carbohydrates and ash (Grosso and Guzman, 1995). Peanut major acids are 8-14% palmitic, 36-67% oleic and 14-44% linoleic along with 5-8% (total) of C:20, C:22, and C:24 saturated and monoene acid (Frank, 2005). Thus, the peroxide value increased with the increase in the period of microwave heating times. Changes in PV values obtained in the present study in good agreement with the previous results in which the PV values increased in oils. Vieira and Regitano (2002) investigated the effects of microwave heating on the oxidative stability of refined canola, corn and soybean oils by measuring absorptivity in the UV spectrum and by chemical analysis (PV and acid values) PV showed a significant difference ($P<0.05$) in the initial stage of heating (0-6 min) for all oils.

Changes in TBA values

The TBA values were taken as a measure for the degree of oxidation during the microwave heating of peanut seeds. Effects of microwave heating time on TBA values of peanut seeds are shown in Figure 3. Sample treated 6.5 min had the highest TBA values without significant ($P>0.05$) different other samples. TBA values were 0.02-0.03 mg/kg. Gou et al. (2000) studied physico-chemical and sensory property changes in almonds found that TBA values increased after an intense toasting process (12 min at 220°C or after 14 min at 200°C). This could be due to the production during the maillard reaction of antioxidant products, which are absorbed in the oil (Sandmeier, 1996)

Changes in free Fatty acids

FFA content is an index of hydrolytic rancidity and contributes to the development of off-flavors and off-odors in the oil. FFA contents (% as oleic acid) increased significantly ($P<0.05$) with the increase in the period of microwave heating times (Figure 4). The maximum increase in FFA was found in sample treated 6.5 min. FFA values were 0.45-0.72 % (as

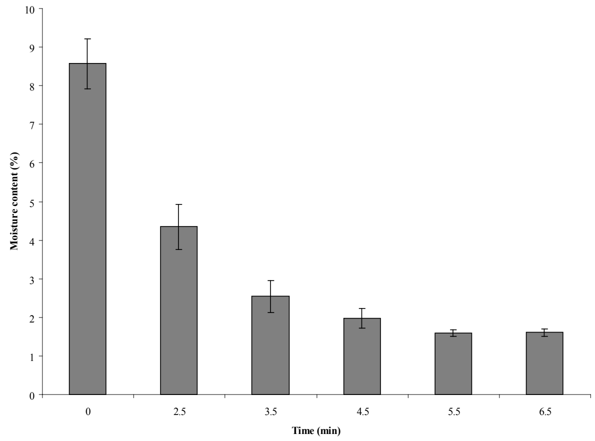

Figure 1. Changes in moisture contents of peanut seeds during microwave heating time

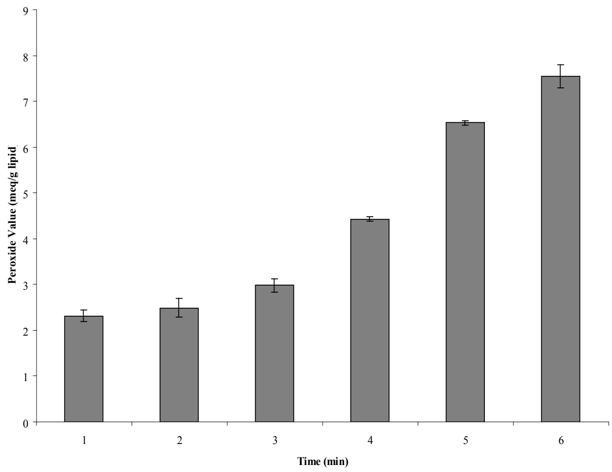

Figure 2. Change in peroxide values of peanut seeds during microwave heating time

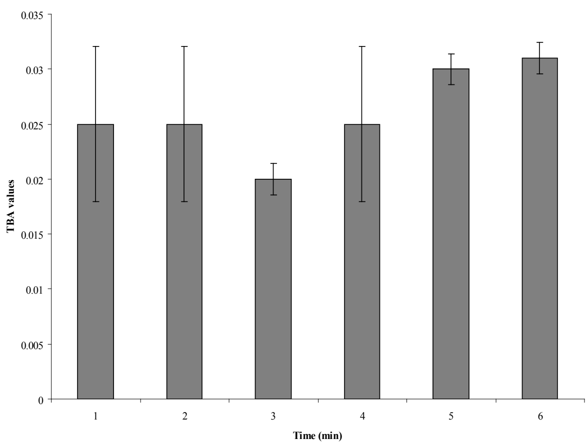

Figure 3. Changes in TBA values of peanut seeds during microwave heating time

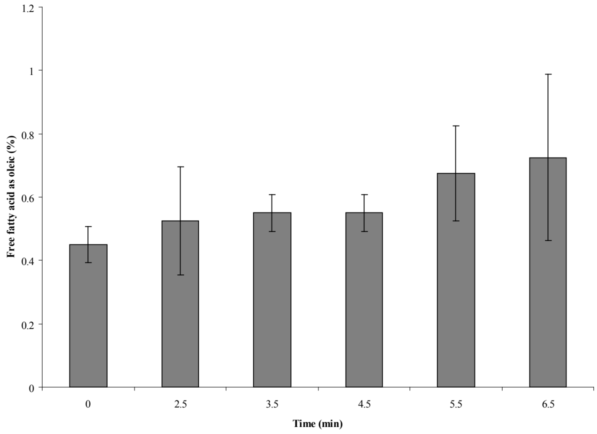

Figure 4. Changes in free fatty acids of peanut seeds during microwave heating time

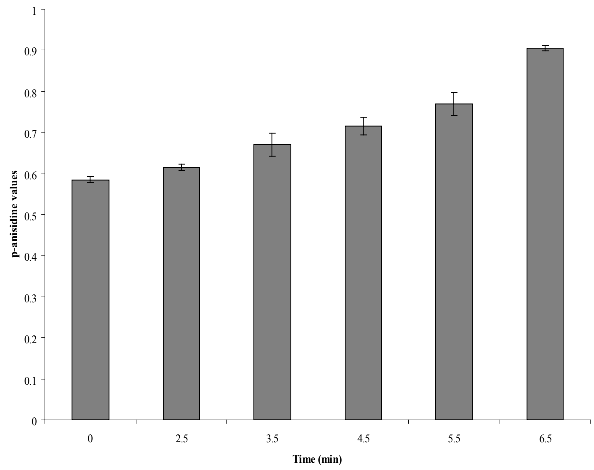

Figure 5. Changes in *p*-anisidine values of seeds during microwave heating time

Table1. Changes in color values of peanut seeds during microwave heating time [a]

Heating time (min)	Color		
	*L**	*a**	*b**
0	70.40±0.87[a]	-0.91±0.98[d]	25.91±0.57[ab]
2.5	69.20±0.26[a]	0.49±1.33[d]	25.85±0.45[ab]
3.5	65.18±0.46[b]	3.15±1.28[c]	29.11±0.47[a]
4.5	56.75±3.41[c]	5.34±2.37[b]	29.80±1.26[a]
5.5	42.36±1.41[d]	8.00±2.37[a]	29.05±4.61[a]
6.5	35.14±4.87[e]	5.44±2.03[b]	24.00±8.46[b]

Different superscripts in the same column indicate significant differences (P<0.05).
a Means ± SD from eight determinations.

oleic acid), in agreement with the result of Yoshida et al. (2002), who found that FFA in sunflower seed oil increased with increasing roasting time. The increase in FFA is undoubtedly due to the splitting of ester linkages of triglyceride molecules as a result of heating. (Yoshida et al., 1992)

Changes in p-anisidine values

P-anisidine values, which generally reflects the magnitude of aldehydic secondary oxidation products in oils (McGinely, 1991), for the peanut seeds with 0-6.5 min microwave heating time changed from 0.58-0.90 (Figure 5). The differences in the *p*-anisidine values between the microwave heating times were statistically significant ($P<0.05$). Literature also revealed a higher extent of formation of secondary oxidation products. Oxidative changes were greater during microwave heating of sunflower, high-oleic sunflower, and olive oils and lard than in a conventional oven under comparable conditions (Albi *et al*., 1997).

Color value

The changes of color value during microwave heating are shown in Table 1. The color values (*L**) of the peanuts increased significantly ($P<0.05$) with the increase in the period of microwave heating time whereas *a** and *b** values increased ($P<0.05$). The color of the peanut seeds changed from light yellow (2.5 min of heating time) to yellow (3.5 min of heating time) to dark brown (6.5 min of heating time). Thus, by increasing the heating time, browning substances were developed. Color development in peanuts depends on the creation of brownish-colored polymeric compound known as melanoidins. Melanoidins are water-insoluble, high molecular weight compounds formed via Maillard browning products that correspond directly to color development in foods. Temperature, heating time, pH, and moisture content play major roles in the formation of colored melanoidin compounds (Ames *et al*., 1994). Yoshida and Kojimoto (1994) and Kim *et al*. (2002) reported that an increase in roasting time and temperature of seeds such as rice germ and sesame seeds resulted in a significant increase in the color of oils. Megahed (2001) reported that oil extracted from peanuts showed gradual darkening and higher Lovibond color indices with increasing heating time.

Acceptability test

The acceptance scores of the effect of microwave heating time in peanut seeds are shown in Table 2. Significant in overall liking of any samples were noticeable after treat microwave heating ($P<0.05$). The acceptability of heated peanut seeds decreased as PV, TBA and *p*-anisidine values increased. Peanut seeds treated with 3.5 min had the highest score for all attributes ($P<0.05$) whereas the lowest scores for all attributes were observed with 6.5 min. This could be due to either lower oxidation resulting in lower amounts of aldehydes that mask peanut flavor

Table2. Acceptability scores of peanut seeds during microwave heating time [a]

Heating time (min)	Attributes				
	Appearance	Color	Texture	Flavor	Overall liking
2.5	6.41±1.36[b]	6.16±1.37[b]	6.00±1.88[b]	5.52±1.74[b]	6.42±1.63[b]
3.5	7.87±1.02[a]	7.74±1.12[a]	7.32±1.33[a]	6.83±1.42[a]	7.77±1.26[a]
4.5	6.10±1.68[b]	6.06±1.63[b]	6.54±1.84[ab]	5.74±1.84[b]	6.10±1.84[b]
5.5	3.51±1.85[c]	3.06±1.75[c]	3.71±2.19[c]	3.87±1.96[c]	3.52±1.82[c]
6.5	2.90±1.75[c]	2.61±1.76[c]	3.61±2.07[c]	2.90±1.74[d]	2.90±1.78[c]

Different superscripts in the same column indicate significant differences (P<0.05).
a Means ± SD from four determinations.

(Warner *et al.,* 1996) or less of pyrazines (Braddock *et al*., 1995). Pyrazines are considered to be the major flavor compounds in peanuts and coffee (Maga, 1991). Thermal processing induces a variety of food flavors which often also contribute aromas such as nutty or caramel (Lindsay, 1985).

Conclusions

In the present work, peanut seeds were oxidized during microwave heating.

The most liking sample was the seeds that treated for 3.5 min. Longer microwave heating time resulted in a greater degree of oil deterioration. Hydroperoxides formed slowly at the beginning and increased gradually as the heating times. The effect of microwave heating time on lipid oxidation was found to be in agreement with the results obtained by Albi *et al*. (1997) and Yoshida and Kajimoto (1994) who studied the effect microwave heating on chemical and physical characteristics of vegetable oils. The results indicated that microwave irradiation on peanut contributed to lipid oxidation and acceptance.

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