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Nutritional Aspects of Thermal and Irradiation Processing of Peanut Kernels and Their Oil

Mahmoud Mohammed Mostafa

Food Science Department, Faculty of Agriculture, Minufiya University, Shebin El-Kom, Egypt

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ABSTRACT

Dry heating at 100°C or 120°C for up to an hour, autoclaving at 121°C for 30 min and exposure to γ-irradiation up to 800 krad could not secure complete inactivation of trypsin inhibitor activity (TIA) of peanut kernels. Roasting at 160°C for 1 h completely inactivated TIA.

Either dry heating or moist heat increased the in-vitro *digestibility of peanut protein as the temperature and/or time of heating increased. γ-irradiation increased protein digestibility with increasing irradiation dose up to 350 krad then gradually declined upon using higher doses.*

Increasing either the roasting temperature or exposure time achieved a slight decrease in acid value accompanied by an increase in peroxide value and a noticeable decrease in iodine value of peanut oil. Accordingly, optimum roasting procedure was found to be 140°C for not more than 30 min. Whereas autoclaving of peanut did not cause any marked changes in oil properties, γ-irradiation decreased the peroxide value without causing noticeable changes in iodine value.

Successive heating of peanut oil at 180°C for up to 60 h caused a gradual increase in both refractive index and flow time. Although the peroxide value increased gradually during the first 8 h, it began to decrease thereafter. Also, a slight increase in acid value was noticed. Oxidized fatty acids increased with increasing heating time while iodine value gradually decreased at 180°C for up to 60 h.

INTRODUCTION

A deficiency in protein supply is one of the most important food problems encountered in most of the developing countries.

Peanut is considered one of the most important legumes and contains considerable amounts of both oil and protein (Ory & Conkerton, 1983). Therefore, it could be incorporated in many food items to raise the level of protein quality and quantity in special diets.

Most studies on the effects of processing on grain legumes have been carried out with soybeans; however, recently groundnuts have received much attention from food technologists (Harris *et al.*, 1972; Neucere, 1972; Pominski & Spadaro, 1973; Hayes *et al.*, 1984).

On the other hand, peanut, like other legumes, contains a trypsin inhibitor that must be inactivated in order to achieve the full nutritional value of the protein (Ory & Neucere, 1971). Consequently, the main objective, in using different domestic and industrial processing methods for peanut kernels, is to find out the optimum treatment for reducing the trypsin inhibitor activity to a minimum; at the same time the treatment should increase palatability without affecting oil quality, alter the bioavailability of nutrients and reduce the rate of formation of beany flavour. The latter is due to the action of the enzyme lipoxygenase on free fatty acids usually present in the raw seed. This leads to the formation of ketones giving undesirable flavours (Walker & Kochhar, 1982). Roasting at a temperature greater than 80°C will denature such enzymes (St. Angelo *et al.*, 1979).

Peanut oil could be used as a frying medium. However, the thermal treatment would induce some deterioration since some oxidized fats polymerize to cause acute toxicity at a dietary level of 2·5% in weaning rats in 7 days (Kummerow, 1962).

Consequently, this work was carried out to study the efficiency of dry heat, moist heat and irradiation for inactivating the antinutritional factors, and to investigate effects on protein digestibility (*in vitro*). Changes in some physical and chemical properties of peanut oil, as affected by thermal treatment, were also investigated.

MATERIAL AND METHODS

Material

Sound peanut kernels (*Arachis hypogaea* L.) of the Giza 4 variety, which represents the major variety grown in Egypt, were obtained from the Seed Department, Agricultural Section, Ministry of Agriculture at Giza, Egypt, in

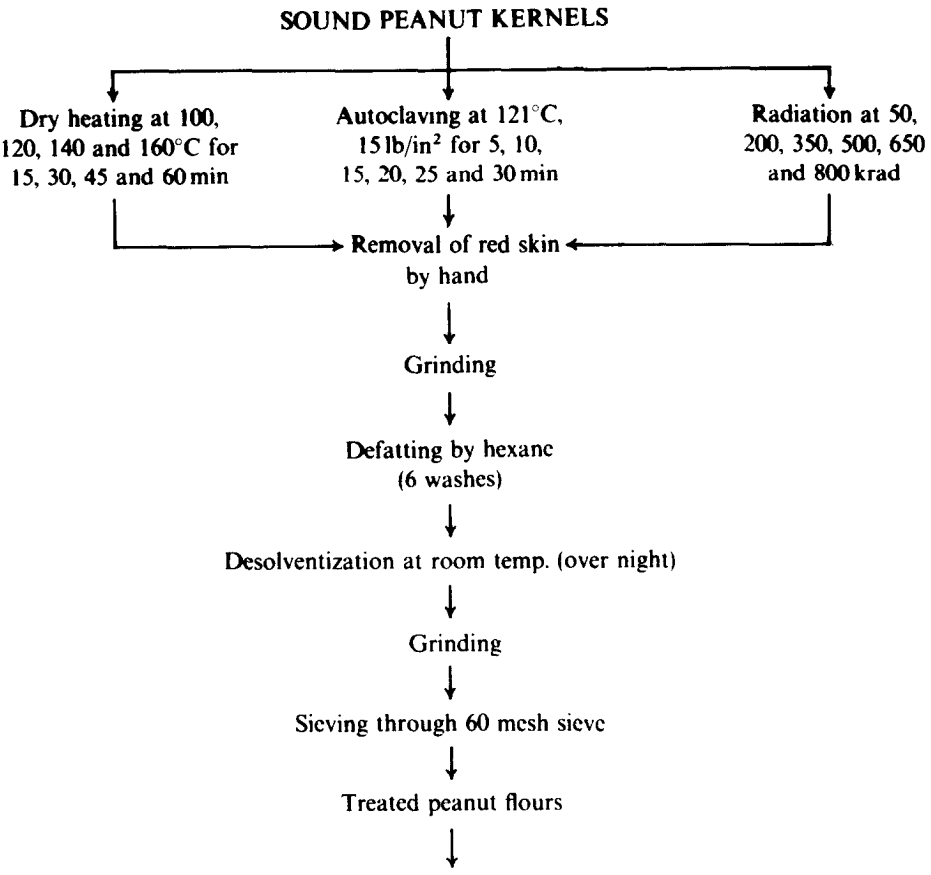

Fig. 1. Diagram for preparing dry, wet heat and irradiated peanut flours.

1985. Peanut kernels used in this experiment were tested for aflatoxin. Peanuts were treated according to the flow sheet shown in Fig. 1.

Thermal treatment of peanut oil

An aliquot (100 ml) of crude peanut oil was heated in a 250-ml beaker at $180 \pm 5°C$ for 60 h. This was done by periods of intermittent heating ($4\,h\,day^{-1}$). Thereafter, oil samples were taken periodically and stored in brown bottles at $-20°C$ for subsequent analysis.

Methods

(1) *Trypsin inhibitor activity (TIA) assay*
The method described by Roy & Bhat (1974) was used for determining the trypsin inhibitor activity in the crude preparation of water extract.

(2) In vitro *digestibility*
The pepsin digestibility (*in vitro*) of peanut flour was determined according to the method of Akeson & Stahmann (1964).

(3) *Oil properties*
Refractive index, acid value, iodine value, peroxide value and oxidized fatty acids were determined according to the methods described by the AOAC (1980). Flow time at 60°C was determined according to Joslyn (1950).

RESULTS AND DISCUSSION

(1) Effect of different treatments on antinutritional factors

(*a*) *Trypsin inhibitor activity* (*TIA*)
Results in Table 1 reveal that TIA of raw peanut meal (control) was 41·7, which is slightly higher than that of soybean (39·8) as reported by Roy & Bhat (1974) and Mostafa *et al.* (1986).

It is clearly observed from the results that roasting treatments induced a noticeable gradual decrease in TIA with increasing temperature and exposure time. Roasting of peanut seeds at either 100 or 120°C for 60 min reduced TIA by 22·4% and 26·6%, respectively. Higher temperature (140 and 160°C) reduced TIA by 84·1% and 100%, respectively. Accordingly, the higher temperature was the most effective method to inactivate TIA. These results are in agreement with those reported by Neucere *et al.* (1972). Consequently, significant improvement in nutritional values could be obtained when compared with raw seeds (Seidl *et al.*, 1969; Ory & Neucere, 1971). On the other hand, autoclaving of peanut kernels did not inactivate

TABLE 1
Effect of Roasting Treatments on Trypsin Inhibitor Activity of Peanut Seeds

Time of roasting (min)	*100°C*		*120°C*		*140°C*		*160°C*	
	TIA[a] *(TUI)*[b]	*Reduction (%)*	*TIA (TUI)*	*Reduction (%)*	*TIA (TUI)*	*Reduction (%)*	*TIA (TUI)*	*Reduction (%)*
Zero (control)	41·7		41·7		41·7		41·7	
15	40·7	2·35	39·9	4·29	32·5	22·0	22·4	46·2
30	37·5	10·2	36·5	12·6	27·8	33·3	20·4	51·2
45	33·8	19·0	32·9	21·2	23·5	43·8	7·43	82·2
60	32·4	22·4	30·6	26·6	6·64	84·1	0·02	100·0

[a] TIA: Trypsin inhibitor activity measured as TUI.
[b] TUI: Trypsin units inhibited.

TABLE 2
Effect of Autoclaving Treatments on Trypsin Inhibitor Activity of Peanut Seeds

Time of auclaving (min)	*TIA[a] (TUI)[b]*	*Reduction (%)*
Control	41·7	—
5	40·0	4·10
10	37·8	9·37
15	35·2	15·6
20	33·8	18·9
25	30·9	25·9
30	28·8	31·0

[a] TIA: Trypsin inhibitor activity measured as TUI.
[b] TUI: Trypsin units inhibited.

TIA as efficiently as dry heating (Table 2). Reduction of TIA amounted to 31% in the case of peanuts heated for 30 min.

Table 3 shows that doses of γ-irradiation up to 800 krad were able to reduce TIA by 22·9% only. Decrease in TIA of peanut meals may be due to the γ-irradiation denaturing the protein inhibitors (Coehlo, 1966).

Conclusively, for dry peanut seeds, heating at either 140°C or 160°C for 1 h was found to be more effective for inactivation of TIA than any other treatments since reductions of TIA were 100·0% and 84·1%, respectively. Therefore, in order to use peanut safely, the shelled seeds should be roasted at 160°C for 1 h to inactivate TIA. Neucere *et al.* (1972) found that a temperature of 145°C for 1 h seemed to be ideal to roast peanut kernels.

TABLE 3
Effect of Gamma Irradiation Treatments on Trypsin Inhibitor Activity of Peanut Seeds

Dose of γ-irradiation (krad)	*TIA[a] (TUI)[b]*	*Reduction (%)*
Control	41·7	—
50	41·7	0·024
200	41·5	0·432
350	41·0	1·80
500	39·8	4·51
650	36·9	11·6
800	32·1	22·9

[a] TIA: Trypsin inhibitor activity measured as TUI.
[b] TUI: Trypsin units inhibited.

(*b*) In vitro *digestibility*

The effects of different heat-treatments on the *in vitro* digestibility of peanut protein by pepsin are given in Fig. 2 (A, B and C). In regard to dry heating, the digestibility increased as the temperature of heating increased. Also there was an obvious increase in the digestibility with increasing time of heating at each temperature. The highest digestibility was 50% after heating at 160°C for 1 h compared to 32% for the control sample (Fig. 2A).

Moist heat showed the same trend and the digestibility increased with increasing time of heating. The maximum digestibility was 56% after moist heat treatment for 30 min (Fig. 2B). Results obtained agree with those reported by Geervani & Theophilus (1980) pertaining to *in vitro* digestibility of the legume protein.

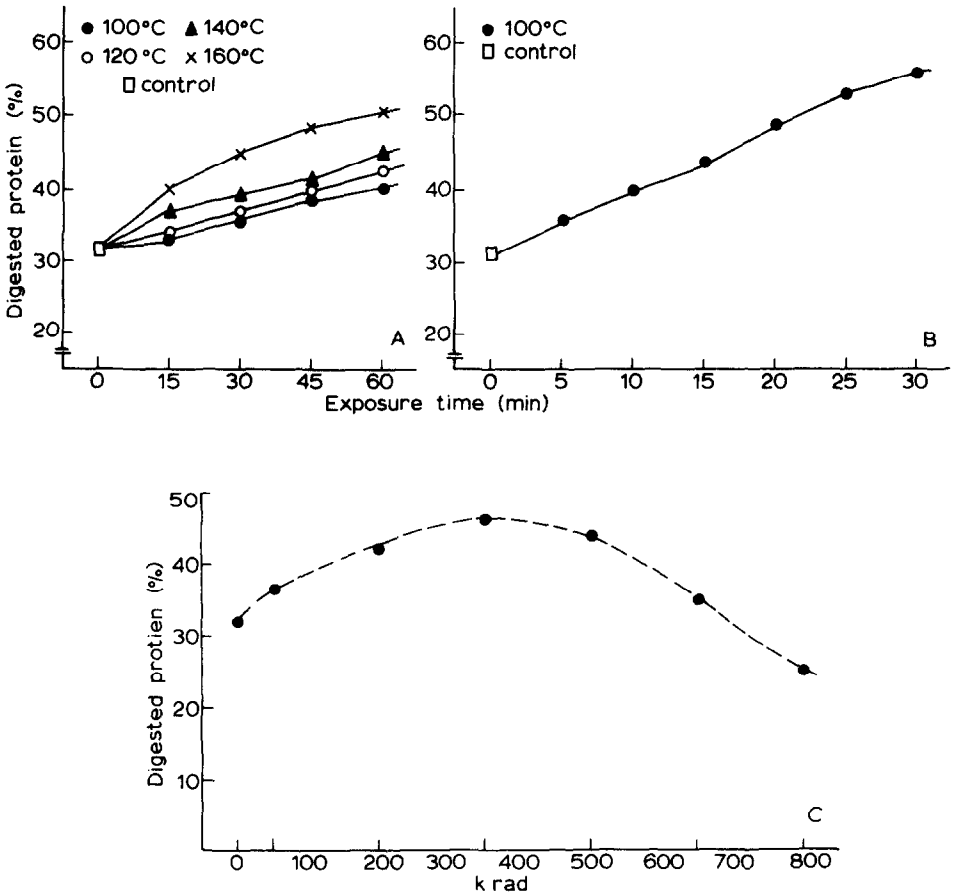

Fig. 2. Effect of (A) dry heat, (B) moist heat and (C) radiation on *in vitro* digestibility of peanut protein.

Figure (2C) illustrates the pepsin protein digestibility for raw and irradiated peanut. The % protein digestibility increased with increasing radiation dose up to 350 krad, then gradually declined upon using higher doses. The raw sample digestibility was 32% whereas the irradiated samples reached a maximum of 46% and decreased to reach 25% when irradiated at the 350 and 800 krad levels, respectively. These results coincide with results of Hsu *et al.* (1977) and Rhee & Rhee (1981). The reduction in digestibility at the higher rate of irradiation could be ascribed to the Maillard reaction and the formation of browning substances which usually have proteolytic inhibitor activity (Hafez & Mohamed, 1983).

(2) Effect of different treatments on some oil properties

Results in Table 4 and Figs 3 and 4 show that the acid value decreased slightly with increasing roasting temperatures, especially for samples exposed for 45 or 60 min. The peroxide value (meq kg^{-1}) increased with increasing roasting temperatures and/or exposure time. The rates of increase in peroxide value due to thermal exposure of roasted peanut at 100°C and 120°C for 60 min, and 140°C and 160°C for only 30 min, were not pronounced since the peroxide values were 2·91, 3·04, 2·34 and 2·74 (meq kg^{-1}), respectively (Fig. 3). On the other hand, roasting of peanut at 140°C and 160°C for more than 30 min induced a marked increase in peroxide value. The increase in this value may be due to the acceleration of dry heat in the presence of air to form peroxide compounds. Therefore, extracted oils from kernels roasted at 140°C and 160°C for 45 and 60 min cannot be considered as edible oils since their peroxide values were 9·67 and 13·8; 16·6 and 18·1, respectively. Such observations are in agreement with those reported by El-Sharkawy *et al.* (1986).

Moreover, roasting treatments, particularly at higher temperatures, i.e. 140°C and 160°C for more than 30 min, induced a noticeable decrease in iodine value of peanut oil (Fig. 4). This decrease in iodine value may be due to either peroxidation of unsaturated bonds, saturation or isomerization of unsaturated fatty acids. These results are in line with those found by Rady *et al.* (1987) when soybean seeds were treated with dry heat.

Accordingly, it could be concluded that, in order to minimize changes which could affect oil quality, peanut kernels must be roasted at 140°C for not more than 30 min.

Humid heat application, by autoclaving for 5 or 10 min, had no effect on either peroxide value or iodine value (Table 5). These results coincide with those of Rady *et al.* (1987) pertaining to soybean.

Autoclaving of peanut for more than 10 min and up to 30 min led to a quite gradual increase in peroxide value. However, acid value and iodine value showed only slight increases with humid heat treatment.

TABLE 4
Effect of Roasting Treatments on Some Characteristics of Peanut Oil

Properties	*Untreated (control)*	*Temperature (°C) and time (min) of roasting*															
		100°C				*120°C*				*140°C*				*160°C*			
		15	*30*	*45*	*60*	*15*	*30*	*45*	*60*	*15*	*30*	*45*	*60*	*15*	*30*	*45*	*60*
Acid value	0·482	0·308	0·386	0·343	0·337	0·324	0·304	0·304	0·298	0·317	0·329	0·305	0·293	0·305	0·284	0·264	0·277
Peroxide value (meq. kg^{-1})	1·29	1·46	2·03	2·25	2·91	1·53	2·23	2·35	3·04	1·55	2·34	9·67	13·8	1·76	2·74	16·6	18·1
Iodine value	86·4	86·3	86·1	85·5	83·8	85·8	85·4	84·8	83·6	85·3	84·7	75·6	70·4	71·7	71·3	67·5	66·4

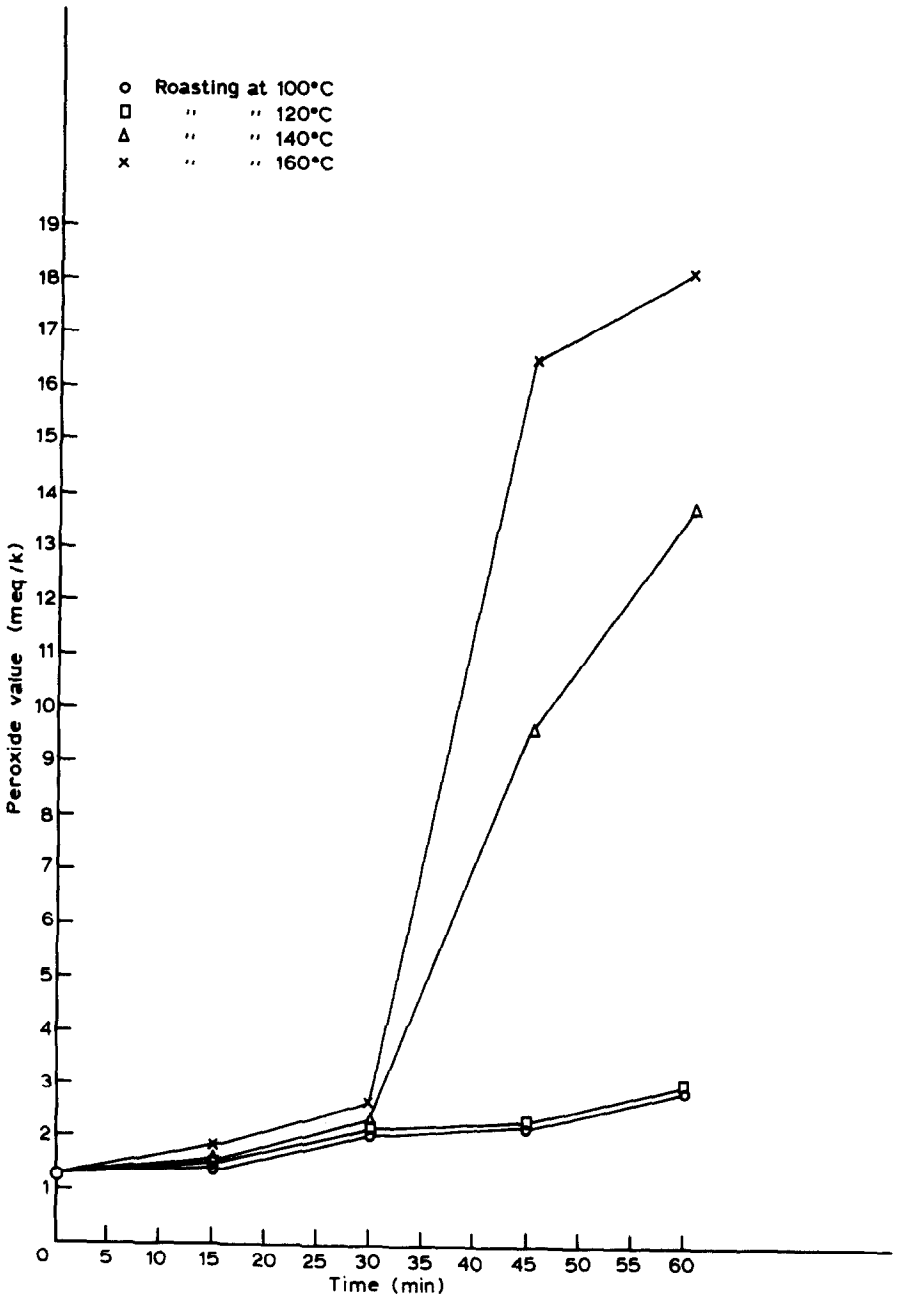

Fig. 3. Changes in peroxide value during roasting of peanut kernels.

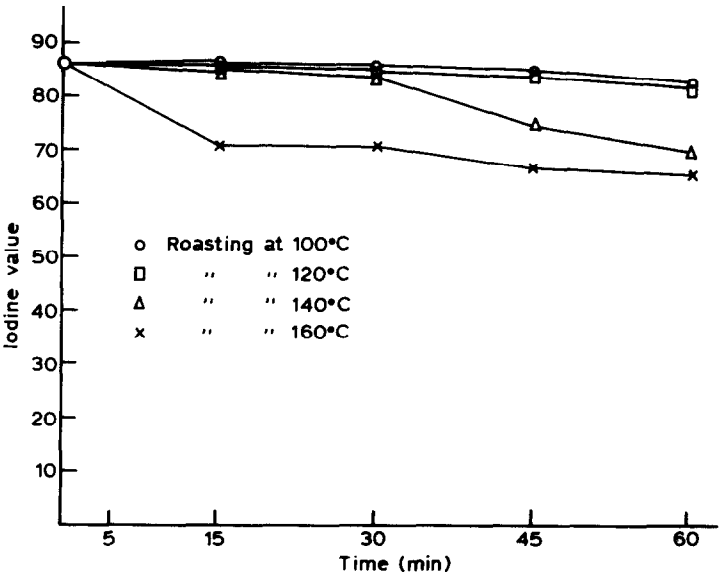

Fig. 4. Changes in iodine value during roasting of peanut kernels.

Generally, from the above results it can be seen that humid heat treatments (autoclaving) caused minor changes in oil properties when compared to dry heat treatments, especially at higher temperature (160°C).

Table 6 shows that the acid value of peanut oil extracted from unirradiated kernels was 0·48 but was only 0·40 after being irradiated (800 krad). Unlike wet or dry heating, the irradiation process had a clear effect in decreasing the peroxide values of oil extracted from irradiated kernels. Untreated peanut oil had a peroxide value of 1·29 but this decreased to 0·97

TABLE 5
Effect of Autoclaving Treatment on Some Characteristics of Peanut Oil

Time of autoclaving (min)	*Properties*		
	Acid value	*Peroxide (meq kg^{-1})*	*Iodine value*
Zero (control)	0·482	1·29	86·4
5	0·287	1·33	86·3
10	0·291	1·37	86·3
15	0·297	2·12	86·0
20	0·314	2·55	85·6
25	0·276	2·83	85·5
30	0·287	2·98	85·4

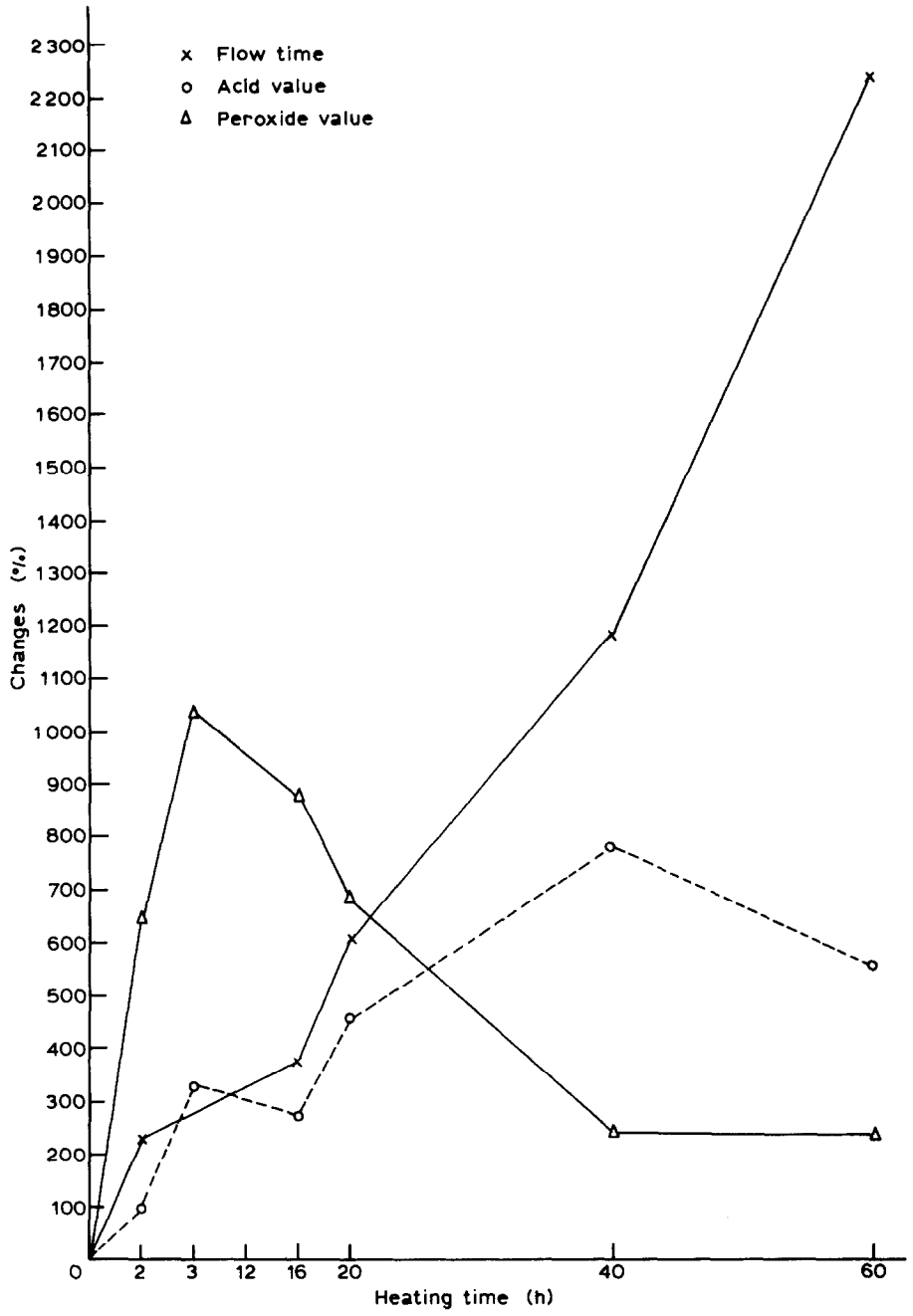

Fig. 5. Per cent changes in some physical and chemical properties of peanut oil during heat treatment.

TABLE 6
Effect of Gamma Irradiation Treatments on Some Characteristics of Peanut Oil

Dose of γ-irradiation (krad)	*Properties*		
	Acid value	*Peroxide value (meq kg^{-1})*	*Iodine value*
Untreated (control)	0·482	1·29	86·4
50	0·487	1·28	86·4
200	0·479	1·23	86·5
350	0·473	1·18	86·5
500	0·470	1·03	86·5
650	0·408	0·97	86·9
800	0·401	0·84	87·1

and 0·84 after being irradiated at 650 and 800 krad, respectively. Iodine values of extracted oil from irradiated and non-irradiated kernels were almost the same (Table 6).

Gamma irradiation of peanut seed using doses up to 800 krad induces slight changes in the chemical properties of peanut oil. These results are in agreement with those of Afifi (1985) working on soybean seeds.

(3) Changes in some physical and chemical properties during heating of peanut oil

Physical and chemical properties of peanut oil were evaluated after thermal exposure. Results (Table 7 and Fig. 5) indicate that gradual increases in both refractive index and flow time occurred due to successive heating at 180°C

TABLE 7
Changes in Some Physical and Chemical Properties of Peanut Oil During Heating

Hours heating	*Refractive index (25°C)*	*Acid value*	*Iodine value*	*Peroxide value (meq kg^{-1})*	*Oxidized FA (%)*	*Relative flow time (60°C)*
0	1·468 4	0·50	86·5	1·73	0·00	116
4	1·474 6	0·99	86·4	13·0	0·42	380
8	1·475 8	2·15	82·5	19·7	0·89	496
16	1·476 0	1·86	80·6	16·9	1·22	555
20	1·477 3	2·79	73·1	13·6	3·68	825
40	1·479 6	4·39	67·4	5·90	7·37	1 490
60	1·481 0	3·29	61·0	5·87	14·2	2 710

up to 60 h. The changes in refractive index and flow time of peanut oil suggested that polymeric materials were present. The increases in refractive indices paralleled the increases in polymeric material as indicated by increasing viscosity of the heated oil. The greatest increase in flow time and refractive index was observed in oil heated for 60 h at 180°C, suggesting rapid polymer formation. The same results also indicate that the flow time increased rapidly after 4 h of heating which is related to oxidized fatty acid percentage and viscosity. The continuation of the heating process for 60 h produced a further increase in refractive index (Table 7) coupled with a very marked increase in flow time. On the other hand, the peroxide value (meq kg^{-1}) increased gradually during heating up to 8 h and then began to decrease (Fig. 5). This decrease could be due to the destruction of the peroxide compounds and the formation of high molecular weight polymerization compounds (El-Sharkawy *et al.*, 1983).

The low peroxide values of the oil which had been heated for 40 and 60 h, when compared with that of the oil heated for 8 h, indicated that these peroxides were not heat stable; consequently, they decomposed to carbonyl and hydroxy acids (Kummerow, 1962). Heating of peanut oil caused an increase in the acid value. Such an increment could be attributed to the formation of both acidic compounds and free fatty acids. Results also show that oxidized fatty acids formed as a result of heating and underwent a marked increase with increasing heating time. This was noticed when using peanut oil in deep frying (Lea, 1962) and during heating of cottonseed oil (El-Sharkawy *et al.*, 1983).

Heating of peanut oil up to 20 h at 180°C revealed that its heat stability was low when compared to cottonseed oil (El-Sharkawy *et al.*, 1983). Such a conclusion coincides with that found by Du Plessis *et al.* (1981) who reported that peanut oil contained less α- and γ-tocopherols (natural antioxidants) than cottonseed oil and that these antioxidants underwent remarkable decreases in their contents during deep frying of peanut oil compared with cottonseed oil.

Iodine value of peanut oil gradually decreased during heating at 180°C for up to 60 h (Table 7). The rate of decrease was relatively low during heating of oil up to 16 h since the initial rate was 6·9% at the first 4 h but reached 29·5% at the end of 60 h of heating. Similar observations have been found by El-Sharkawy *et al.* (1983) pertaining to cottonseed oil.

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REFERENCES

Afifi, E. A. M. (1985). *Effect of gamma irradiation on some plant oils.* MSc Thesis, Fac. of Agric. at Moshtohor, Zagazig. Univ.

Akeson, W. & Stahmann, A. M. (1964). A pepsin pancreatin digest index of protein quality evaluation. *J. Nut.*, **83**, 157.

AOAC (1980). *Official methods of analysis.* (12th edn), Assoc. of Official Analytical Chem., Washington, DC.

Coehlo, R. (1966). *Int. Cong. Radiat. Res., Cortina Apezzo, Italy, 26 June–2 July.*

Du-Plessis, L. M., Twisk, P. V., Niekerk, P. J. V. & Steyn, M. (1981). Evaluation of peanut and cottonseed oils for deep frying. *J. Amer. Oil Chem. Soc.*, **5**, 575–8.

El-Sharkawy, A. A., Mostafa, M. M., Rady, A. H. & El-Kalubi, M. (1983). Improving the heat stability of cottonseed oil. *Minufiya, J. Agric. Res.*, **7**, 195–213.

El-Sharkawy, A. A., Rady, A. H., Mostafa, M. M. & Kandil, S. H. (1986). Changes in main components of raw and roasted peanut and sesame seeds. 1. Oil properties, fatty acids composition, hydrocarbon and sterol constituents. *Egypt J. Food Sci.*, **14**(1), 13–22.

Geervani, P. & Theophilus, F. (1980). Effect of home processing on the protein quality of selected legumes. *J. Food Sci.*, **45**, 707.

Hafez, Y. S. & Mohamed, A. I. (1983). Presence of nonprotein trypsin inhibitor in soy and winged beans. *J. Food Sci.*, 48–75.

Harris, H., Davis, E. Y., DeMark, M. S. V., Rymal, K. S. & Spadaro, J. J. (1972). Development and use of defatted peanut flours, meals, and grits. *Agric. Exper. St. Auburn Univ., Bull. 431*, 5–68 Auburn, Alabama, USA.

Hsu, H. W., Varak, D. L., Satterlee, L. D. & Miller, G. A. (1977). A multienzyme technique for estimating protein digestibility, *J. Food Sci.*, **42**, 1269.

Hayes, R. E., Spadaro, J. J., Wadsworth, J. I. & Freeman, D. W. (1984). *A study of nine corn based food blends formulated by computer for maximum protein quality.* Agric. Res. Service, US Dept. of Agric., PO Box 53326, New Orleans, La. 70153.

Joslyn, M. A. (1950). *Methods in food analysis.* Academic Press Inc., Publishers, New York.

Kummerow, F. A. (1962). Toxicity of heated fats. *Symposium on Foods: Lipids and their Oxidation.* The AVI Pub. Co., Inc., 294.

Lea, C. H. (1962). The oxidative deterioration of food lipids. *Symposium on Foods: Lipids and their Oxidation.* The AVI Pub. Co., Inc., 20.

Mostafa, M. M., Rady, A. H. & Rahma, E. H. (1986). Effect of different technological methods on the quality of soybean oil and meal. *Egypt J. Food Sci.*, **14**(2), 409–19.

Neucere, N. J. (1972). Effect of heat on peanut proteins. Solubility properties and immunochemical-electrophoretic modifications. *J. Agric. Food Chem.*, **20**(2), 252–5.

Neucere, N. J., Conkerton, E. J. & Booth, A. N. (1972). Effect of heat on peanut

proteins. II. Variations in nutritional quality of the meals. *J. Agr. Food Chem.*, **20**(2), 256–9.

Ory, R. L. & Neucere, N. J. (1971). An indirect immunochemical assay for trypsin inhibitor activity in peanuts. *J. of Amer. Peanut Res. and Educ. Assoc., Ind.*, **3**(1), 57–62.

Ory, R. L. & Conkerton, E. J. (1983). Supplementation of bakery items with high protein peanut flour. *J. Amer. Chem. Soc.*, **60**(5), 986–9.

Pominski, J. & Spadaro, J. J. (1973). Peanut protein foods. *Peanut Journal & Nut World*, **52**(11), 6–29.

Rady, A. H., Mostafa, M. M. & Rahma, E. H. (1987). Effect of humid and dry heat application on the quality of soybean oil and cake residue. *Egypt. J. Food Sci.*, **15**(1), 37–50.

Rhee, K. & Rhee, K. C. (1981). Nutritional evaluation of the protein in oil seed products heated with sugar. *J. Food Sci.*, **46**, 164.

Roy, D. N. & Bhat, R. V. (1974). Trypsin inhibitor content in some varieties of soya bean (*Glycine max*, L.) and sunflower seeds (*Helianthus annuus*, L.). *J. Sci. Food Agric.*, **25**, 765–9.

Seidl, D. M., Jaffe, M. & Jaffe, W. G. (1969). Digestibility and proteinase inhibitory action of a kidney bean globulin. *J. Ag. Food Chem.*, **17**, 1318–21.

St. Angelo, A. J., Kuck, J. C. & Ory, R. L. (1979). Role of lipoxygenase and lipid oxidation in quality of oilseeds. *J. Agric. Food Chem.*, **27**(2), 229–34.

Walker, A. F. & Kochhar, N. (1982). Effect of processing, including domestic cooking, on nutritional quality of legumes. *Proc. Nutr. Soc.*, **41**(1), 41–51.