Intl. J. Food. Ferment. Technol. 8(2): 161-169, December 2018

DOI: 10.30954/2277-9396.02.2018.5

RESEARCH PAPER

Comparison of Conventional, Microwave and Infrared Roasting Methods on the Changes in Physico-chemical and Antioxidant Properties of Peanuts (*Arachis hypogaea*)

Atul Kumar, Padmashree, A., Govindraj, T., Semwal, A.D. and Sharma, G.K.*

Defence Food Research Laboratory, Siddarthanagar Mysuru-570 011, India

*Corresponding author: gk.sharma@dfrl.drdo.in

Paper No.: 217 **Received:** 11-07-2018 **Revised:** 16-10-2018 **Accepted:** 25-11-2018

ABSTRACT

The effect of microwave and Infrared roasting methods on the physico-chemical and antioxidant properties of peanuts (*Arachis hypogaea)* were studied and the results were compared with conventional roasting methods. Roasting by all the three methods significantly affected the moisture, total protein and total fat contents. Protein and fat contents increased significantly ($p \leq 0.05$) with the significant ($p \leq 0.05$) decrease in moisture content. However, roasting by all the methods did not cause any significant change in the mineral contents. Chemical changes like PV, FFA and TBA increased significantly ($p \leq 0.05$) more during conventional roasting in comparison to the microwave and IR roasting of peanuts. Total phenols, total flavonoids and antioxidant activity were found significantly ($p \leq 0.05$) higher in peanut skin as compared to their kernel part, and roasting enhanced them significantly though the increase in absolute term was small. Polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) decreased significantly ($p \leq 0.05$) with the concomitant increase in their saturated fatty acid (SFA) contents but the observation was more true in peanuts treated by conventional roasting methods. Between microwave and IR roasting, the above changes were found almost insignificant.

Keywords: Peanuts, Roasting, Conventional, Microwave, Infrared, Physico-chemical, Antioxidant activity

Roasting is a time dependent heating process applied to some foods mainly to promote flavour changes that ultimately influences the overall quality and palatability of foods. When certain foods especially nuts such as peanut, almonds, hazelnut etc are subjected to roasting, many volatiles compounds are released after a certain stage of heating, which results in the enhancement of flavour and taste characteristics (Buckholz *et al.* 1980). Roasting not only enhances the flavour of foods, but also changed amino acids, peptides (Montavon *et al.* 2003), tocopherol, fatty acids and lignins (Murkovic *et al.* 2004). The roasting at the same time were found to destroy, undesirable microorganisms, toxins or allergens and enzymes responsible for the nutrient loss and browning could be inactivated (Ozdemir and Devres, 1999) by roasting. Roasting also found to enhance various antioxidant compounds in earlier study (Mar Mar Win *et al.* 2011)

Microwave energy has been used since early 1960's for various food applications such as thawing, drying, baking, roasting etc (Villameil *et al.* 1996). Microwaves are referred to as electromagnetic waves which works in the range of 300 to 300,000 MHz. Heating takes place mainly due to the dipole excitation or ion migration and friction energy is produced due to the orientation of dipole in the altering electromagnetic field (Rosenberg and Boggle, 1987). Radiation penetrates deeply and heat the substance rapidly and instantaneously (El Badrawy *et al.* 2007).

Infrared (IR) heating of foods is also receiving much popularity during recent years due to its various advantages over other methods of heating. IR falls between microwave and radio waves and its spectrum ranges from 0.72 to 1000µM, divided into short, middle and far IR regions (Krishnamurthy *et al*. 2008). Most of the food materials to be heated falls under far IR region which works between the wavelength of 4 to 1000µm and coincides with the surface temperature of 0 to 450 °C. Literature highlights many examples of baking, cooking, blanching and roasting using IR energy. Both microwave and IR roasting have the advantages of having short time processing methods which proves to be the best alternative roasting techniques in terms of achieving uniformity in providing temperature distribution inside the product in comparison to the conventional roasting methods. Moreover, conventional methods of roasting requires more time to transfer thermal energy from product surface towards the centre (El-Badrawy *et al.* 2007).

Peanuts are widely grown in India and is an important oil seed crop consumed all over the world. Recently, the crop has received much attention as a functional food (Franscisco and Resurrection, 2008). The crop is considered to be important for the production of oil (Fakriya *et al.* 2012) and more than one third of peanut cultivars grown world wide is used as a food (Sanders, 2002). Peanuts are usually roasted before consumption and before adding to any foods either as a whole kernel or in the ground form. Traditional roasting methods is usually time consuming and may affect the constituents of peanuts especially lipids, which may undergo lipid oxidation leading to rancidity which adversely affects its quality and stability of peanuts during storage.

Therefore, the present work was focussed at comparing microwave and infrared roasting with the conventional roasting of peanuts and to study the effect of these roasting techniques on its physico-chemical changes by carefully controlling the above heating methods to minimise nutritional, oxidative and sensory changes which ultimately determines the products quality and acceptability.

MATERIALS AND METHODS

Materials

Peanut (*Arachis hypogea)* was obtained from the local market of Mysuru, India. All seeds were manually cleaned and foreign components were removed.

2, 2,-Diphenyl-1, Picryl hydrazyl DPPH), Folins-ciocalteau (FC) reagent, Butylated hydroxy anisole (BHA), Gallic acid standard, were purchased from Sigma- Aldrich, Mumbai.2-thiobarbituric acid and P-anisidine were purchased from Fluka chemicals, Mumbai. All other chemicals and solvents used were of analytical reagent grade.

Methods

Microwave Roasting

2 kg of sound and cleaned peanuts, 500 g per batch was roasted in a domestic microwave oven (Model: MG607APR, LG make) till seeds generated roasted aroma, which took 3.5 min. Peanuts were cooled to room temperature, de-skinned and stored in polyethylene pouches at 4 °C, till further use.

IR Roasting

2 kg of peanuts were passed through Infrared (IR) heaters mounted with electrically powered ceramic heating elements (1000 watt) having the capacity of 40 kg/h (Therman Heating Technologies Pvt. Ltd., Bangalore, India) and that could be operated up to 900 °C. Peanuts were IR heated at 450 °C (4 times) which took approximately 4 min. Seeds were cooled to room temperature, de-skinned and stored in polyethylene pouches at 4 °C, till further use.

Conventional roasting

Similarly, peanut seeds were roasted in an open pan for 20 min till it attained a temperature of 180 °C to obtain a product of desired quality with crumbly texture and roasted aroma. After roasting, the seeds were cooled, de-skinned and stored as above. Peanuts after roasting by all the above 3 methods were ground to pass through 30 mesh sieve and used for experimental purpose.

Physico-chemical characteristics

Moisture, total ash, crude protein and crude fat in roasted peanuts were determined by the methods described by (AOAC, 1984). Mineral content was estimated by using atomic absorption spectrophotometer (Model: Vario 6, Analytik Jena, Germany) as per the method of Khan *et al.* (2008). Fatty acid composition of the lipid extracted from pea nut was determined using standard (AOCS 1990) methods. The total phenolic content of raw and roasted kernel flours as well as peanut skin was determined as per the method described by Singleton *et al.* (1999). Total flavonoids in raw, roasted kernel flours and their skin was carried out as per the method of Jia *et al.* (1999). The radical scavenging activity of raw, roasted pea nut kernel flour as well as their skin was determined using DPPH free radical according to the method described by Yuan *et al.* (2005) with slight modifications.

Colour value measurement

The CIE colour values (L^*, a^*, b^*) were measured using D-65 illuminant and 10^0 observer using a colour meter (MINISCAN XE PLUS, MODEL 45/0-S, HUNTER ASSOCIATES LABORATORY, INC., RESTON, VA, USA). Standard white and black tiles were used as a reference. Triplicate readings were carried out for each sample and average of the same has been reported.

Sensory evaluation

Sensory evaluation of raw as well as roasted pea nut kernels were carried out by 20 semi- trained panel of judges and asked to grade the product in terms of colour, aroma, taste, texture and over-all acceptability on a 9-point Hedonic scale, with 9 as excellent in all respects and 1 for highly disliked samples (Larmond, 1977). Samples of each treatment were placed in individual dishes (diameter 5 cm). A balance incomplete block design was used to group the samples (Meilgaard *et al.* 1990). Each pannelist was assigned a block containing all the four samples coded as A, B, C , D in a random order in a sensory evaluation room specially designed for conducting sensory evaluation of the food samples.

Statistical analysis

All the reported values are mean of three replicates and were subjected to one way analysis of variance (ANOVA). Significant differences ($p \leq 0.05$) between the means were tested by Duncan's multiple range test using statistical software (Statistica, Ver. 7.1 Series 1205) at $P \leq 0.05$ significance levels.

RESULTS AND DISCUSSION

Proximate composition of peanuts roasted by conventional, microwave and IR methods along with unprocessed raw sample is represented in the Table 1. Raw peanut showed moisture content of 5.36%. It is evident from the results that, though all the three types of roasting had significantly ($p \leq 0.05$) decreased the moisture contents, but the microwave roasted ones attributed more reduction and the reduction was found to be from 5.36 to 2.47%. Moisture content

Table 1: Comparison in proximate composition of conventional, microwave and IR roasted peanuts (n=3)

	Moisture (%)	C. Protein (%)	C. Fat (%)	T. Ash (%)	T. Carbohydrate (%)	Energy (K Cal)
Raw	5.36 ± 0.07^d	26.38 ± 0.02^a	46.79 ± 0.07^a	2.70 ± 0.07^a	18.77 ± 0.06^a	601.71 ± 0.06^a
Conventional	3.63 ± 0.06^c	27.79 ± 0.16^b	46.92 ± 0.08^a	2.76 ± 0.14^a	18.90 ± 0.06^b	609.04 ± 0.10^b
Microwave	2.47 ± 0.05^a	28.76 ± 0.09^d	47.26 ± 0.08^b	2.79 ± 0.07^a	18.72 ± 0.17^a	615.26 ± 0.06^d
IR	3.26 ± 0.06^b	27.98 ± 0.15^c	47.22 ± 0.04^b	2.78 ± 0.11^a	18.77 ± 0.16^a	611.98 ± 0.10^c

Values with different superscripts in columns differ significantly ($p \leq 0.05$)

Values are mean ± SD

C.Protein - Crude Protein, C.Fat- Crude fat, T.Ash – Total Ash, T.Carbohydrate –Total carbohydrate.

in IR and conventionally roasted pea nuts were found to be 3.26 and 3.63%, respectively. Total ash content increased insignificantly by the roasting methods used. Roasting of peanuts by all the 3 methods has caused a significant ($p \leq 0.05$) increase in their protein contents. Raw peanuts showed 26.38% protein. After roasting, protein was found to be highest in microwave roasted pea nuts (28.76%) in comparison to IR (27.98%) as well as conventionally roasted pea nuts (27.79%). The increase in protein contents may be ascribed to the reduction in their anti-nutrients, and also due to the disruption of protein structure during heating (Neilsen 1991). Adu *et al.* (2015) also reported a significant increase in protein content after thermal processing of Indian almond seeds. Unprocessed raw peanut showed 46.79% fat. Significant ($p \leq 0.05$) increase in fat content was observed between the raw and microwave, raw and IR as well as conventional and microwave methods of roasting. The disintegration of inherent organic compound to release more free fat molecules is attributed to the increase in fat content at higher temperatures (Makinde and Oladunni, 2016). However between raw and conventional, microwave and IR method of roasting, no significant change ($P \geq 0.05$) changes in the fat content was observed. The increase in fat content in peanuts roasted by all the three methods was found to be in the range of 46.92 to 47.26%. Carbohydrate content calculated by difference and the calorific value of pea nuts roasted by all the methods were found be in the range of 18.72-18.90% and 601.71 to 615.26 K Cal, respectively.

Effect of different roasting methods on the mineral composition

Roasting has not caused any significant change in the content of minerals tested wrt to the unprocessed peanuts except sodium, iron and copper, which may be due to the slight differences in replication of results. Since total ash content remained unchanged, has not significantly affected the different minerals estimated in our study. Between unroasted and roasted samples of peanut, calcium content ranged from 87.13 to 87.28 mg/100g, magnesium 159.33 to 159.41 mg/100g, potassium 708.25 to 709.30 mg/100g, sodium 16.57 to 17.13 mg/100g, iron 4.48 to 5.63mg/100g, zinc 2.98 to 3.07mg/100g, copper 0.93 to 1.13 mg/100g and manganese 1.29 to 1.37 mg/100g (Table 2). The results for minerals obtained from our study stands on par with the values reported by (Asibuo *et al.* 2008) except for potassium which showed comparatively higher amounts in different varieties of peanuts.

Effect of different roasting methods on the changes in colour

Roasting by conventional, microwave and IR methods have significantly influenced colour changes in peanut kernels (Table 3). Lightness index (L^*) decreased significantly ($p \leq 0.05$) from 71.30 to 59.83 in conventionally roasted, 65.13 in microwave roasted, and 64.87 in IR roasted peanuts. With the decrease in L^* value, a^* and b^* values increased significantly ($p \leq 0.05$) and as expected were found comparatively more in conventionally roasted peanuts. The colour of the raw peanut kernel, which was very light yellow, turned to slightly dark yellow when roasted by microwave and IR, and still darker yellow when roasted by conventional methods due to the formation of comparatively more melanoidins via maillard reaction. The changes in L^* a^* and b^* values between microwave and IR were not found significant ($p \geq 0.05$). It has been reported that the colour changes in many roasted products are mainly due to the non-enzymatic browning reactions only, since enzymes responsible for enzymic browning gets denatured during roasting process (Driscoll and Madamba, 1994).

Total phenols, Total flavonoids and antioxidant activity of peanuts

Poly-phenolic compounds are found to be present in the outer layers of plants, parts of shell, hull and peel to protect their inner layers (Scalbert *et al.* 2005). Therefore in the present study, skin was separated from unprocessed raw, conventionally, microwave and IR roasted peanuts and were used for carrying out total phenolics, total flavonoids and antioxidant activity along with their respective kernel counterparts.

Table 2: Comparison in mineral contents of conventional, microwave and IR roasted pea nuts (n=3)

Roasting methods	Ca (mg/100g)	Mg (mg/100g)	K (mg/100g)	Na (mg/100g)	Fe (mg/100g)	Zn (mg/100g)	Cu (mg/100g)	Mn (mg/100g)
Raw	87.13 ± 0.26[a]	159.38 ± 0.31[a]	708.25 ± 0.04[a]	16.57 ± 0.03[a]	4.48 ± 0.03[a]	2.98 ± 0.05[a]	0.93 ± 0.02[a]	1.37 ± 0.11[a]
Conventional	87.28 ± 0.17[a]	159.33 ± 0.29[a]	708.49 ± 0.11[a]	17.13 ± 0.05[b]	4.99 ± 0.07[b]	3.02 ± 0.11[a]	1.13 ± 0.05[c]	1.29 ± 0.09[a]
Microwave	87.19 ± 0.20[a]	159.41 ± 0.21[a]	708.30 ± 0.10[a]	16.96 ± 0.04[c]	5.63 ± 0.10[d]	3.07 ±0.08[a]	0.98 ± 0.04[b]	1.31 ± 0.10[a]
IR	87.13 ± 0.13[a]	159.49 ± 0.09[a]	709.30 ±0.07[b]	16.83 ± 0.09[d]	5.53 ±0.02[c]	3.05 ± 0.07[a]	0.97 ± 0.04[b]	1.37 ± 0.09[a]

Values with different superscripts in columns differ significantly (p≤0.05); Values are mean± SD.

Table 3: Comparison in colour value of conventional, microwave and IR roasted peanuts (n=3)

Roasting methods	L*	a*	b*
Raw	71.30±0.17[c]	0.19±0.10[a]	24.97±0.12[a]
Conventional	59.83±0.23[a]	4.33±0.64[c]	28.81±0.39[c]
Microwave	65.13±0.18[b]	3.74±0.09[b]	26.53±0.47[b]
IR	64.87±0.20[b]	3.93±0.15[b]	27.11±0.25[b]

Values with different superscripts in columns differ significantly (p≤0.05); Values with mean± SD.

Table 4: Changes in Total phenols, Total flavonoids and antioxidant activity of conventional, microwave and IR roasted peanut skin and kernel (n=3)

Roasting methods	Peanut skin			Peanut kernel		
	T.phenols	T.Flavonoids	AOA	T.phenols	T.Flavonoids	AOA
Raw	97.44±0.14a	59.22±0.09a	81.69±0.40a	0.89±0.19a	10.24±0.09a	7.30±0.10a
Conventional	103.96±0.23c	65.10±0.20b	87.08±0.27b	1.04±0.09b	12.64±0.07b	8.53±0.06b
Microwave	107.47±0.25d	71.11±0.20d	89.15±0.19c	1.18±0.05b	15.27 ±0.08d	9.72±0.26c
IR	102.42±0.17b	68.00±0.18c	89.09±0.29c	1.11±0.08b	14.66±0.05c	9.31±0.06c

Values with different superscripts in columns differ significantly (p≤0.05); Values with mean± SD.

Total Phenols (mg gallic acid equivalent/g), Total Flavanoids (mg catechin equivalent/g), AOA- Antioxidant activity (% inhibition).

Results of the study showed that, total phenolics and flavonoids of peanut skin were found comparatively higher than their kernel. Skin portion showed 97.44 and 59.22 mg/g of total phenolis and flavonoids while kernel part showed 0.89 and 10.24 mg/g of the same respectively (Table 4). The higher amounts of phenols found in the peanut skin than their kernel portion may be due to proanthocyanidins, a phenolic compound present in skin (Yvonne *et al.* 2007). Roasting by all the three methods showed slight but significant (p≤0.05) increase in total phenolics in peanut skin, while the same in kernel part remain unchanged. Less but significant (p≤0.05) improvement in total flavonoids were found in both skin and kernel portions after each roasting process. Among different roasting methods carried out, the increase in flavonoid was found to be from 65.10 to 71.11mg/g in peanut skin and 12.64 to15.27 mg/g in peanut kernel.

Phenolic compounds found in plant act as powerful antioxidants due to their ability to donate hydrogen or electron to form stable radical intermediates (Scalbert *et al.* 2005). In the present study, the radical scavenging activity of unprocessed raw and roasted peanut skin as well as their kernel part was determined by DPPH method. Since roasting has slightly enhanced total phenolics and flavanoids, a slight but significant ($p \leq 0.05$) improvement in the radical scavenging activity was observed in both skin and kernel part. Unprocessed peanut skin as well its kernel showed a radical scavenging activity of 81.69 and 7.3% respectively and the same has been increased to 87.08 8.53, 89.15 9.72 and 89.09, 9.31% after conventional, microwave and IR roasting, respectively. Between Microwave and IR roasting, both skin and kernel portion of peanuts have shown insignificant ($p \geq 0.05$) changes in their antioxidant activities.

Effect of different roasting methods on the chemical changes

Heating at different temperatures greatly influences the rate of lipid oxidation of foods. When lipid containing foods are heated at elevated temperature, oxidative decomposition such as hydro-peroxide formation and secondary oxidation proceeds at a faster rate, results in the development of off odour leading to rancidity.

Table 5 depicts the effect of microwave, IR and conventional roasting methods on the oxidative stability of peanut kernel. Peroxide value (PV) of raw peanut was 5.52 meq o_2/kg fat. Conventional roasting has increased PV significantly ($p \leq 0.05$) to 6.44 meq o_2/kg fat. However, microwave and IR roastings have not caused any major changes in the peroxide value of peanuts. FFA value was found to increase significantly ($p \leq 0.05$) from 0.64% oleic acid in unprocessed raw samples to 0.87% oleic acid in conventionally roasted samples. However, among the microwave and IR roasted peanut kernel flour, increase in FFA value was found insignificant ($p \leq 0.05$). The increase in FFA value could be attribute to splitting of ester linkages of triglycerides as a result of heating (Yoshida *et al.* 1992). It is clear from the data that, conventional, microwave and IR roasting methods have significantly decreased ($p \leq 0.05$) the degree of unsaturation of peanut oils as indicated by the iodine value. Raw pea nut showed 87.77 units of iodine value and it decreased significantly ($p \leq 0.05$) to 84.02, 83.29 and 83.57 units upon conventional, microwave and IR roasting respectively. Malonaldehyde formation was also observed significantly more in conventionally roasted peanuts as compared to microwave and IR roasted pea nuts. Raw pea nuts exhibited a TBA value of 0.60 mg malonaldehyde/ kg sample, while conventional roasted ones showed 1.26 mg of malonaldehyde/ kg sample. Microwave and IR roasted ones showed TBA value of 0.65 and 0.63 mg malonaldehyde/kg sample respectively. p-anisidine value which measures two alkenals, a secondary degradation product also found to enhance significantly during all the methods of roasting. It enhanced from 0.40 (raw) to 0.83, 0.74 and 0.72 units during conventional, mircrowave and IR roasting respectively. Refractive index however did not show any significant changes during all the methods of roasting carried out.

Table 5: Changes in peroxide value, free fatty acids, Thiobarbituric acid value, Iodine value, Anisidine value (AV) and Refractive index (RI) of conventional, microwave and IR roasted pea nuts (n=3)

Roasting methods	PV	FFA	TBA	IV	AV	RI
Raw	5.52 ± 0.15^a	0.64 ± 0.04^a	0.60 ± 0.06^a	87.77 ± 0.03^d	0.40 ± 0.01^a	1.473 ± 0.0004^a
Conventional	6.44 ± 0.30^d	0.88 ± 0.42^c	1.26 ± 0.11^b	84.02 ± 0.10^c	0.83 ± 0.06^c	1.474 ± 0.0002^a
Microwave	5.87 ± 0.04^c	0.74 ± 0.04^b	0.65 ± 0.05^a	83.29 ± 0.09^a	0.74 ± 0.03^b	1.473 ± 0.0007^a
IR	5.66 ± 0.05^b	0.73 ± 0.04^b	0.63 ± 0.04^a	83.57 ± 0.25^b	0.72 ± 0.03^b	1.473 ± 0.0004^a

Values with different superscripts in columns differ significantly ($p \leq 0.05$).

Values with mean± SD.

Peroxide value (meqO_2/kg fat), Free fatty acids (FFA, % Oleic acid), Thiobarbituric acid value (TBA, mg malonaldehyde/kg sample), Iodine value (IV), Anisidine vslue (AV,) and Refractive index (RI).

Effect of different roasting methods on the fatty acid composition

Six fatty acids could be identified in the lipid extracted from raw and roasted pea nut flours constituting 92.42% of the total fatty acids, of which oleic (41.72%) and linoleic (34.03%) acids were found to be the abundant ones (Table 6). It is clear from the data that, roasting has undoubtedly affected the composition of different fatty acids present in the peanut kernel irrespective of the roasting methods used. Fatty acids got degraded at much higher amounts during conventional roasting than microwave and IR roasting. However, microwave and IR roasting have significantly reduced the degradation of fatty acids in peanut kernel. Polyunsaturated fatty acids constituting linoleic and linolenic acids decreased significantly ($p \leq 0.05$) from 35.94% (unprocessed raw) to 31.20% in conventionally roasted, 33.63% in microwave roasted and 33.10% in IR roasted peanut kernels. The concomitant increase in saturated fatty acids were found to be from 14.76% to 22.34, 19.86 and 20.75%, respectively.

Effect of different roasting methods on the sensory changes

The changes in sensory attributes of unprocessed raw as well as conventional, microwave and IR roasted pea nuts are presented in the Table 7. Peanuts roasted by all the three methods underwent significant changes in sensory attributes as evaluated in terms of colour, aroma, taste, texture and over all acceptability on a 9 point Hedonic scale. The sensory changes between microwave and IR roasted pea nuts were not found significant ($P>0.05$). The colour of microwave and IR roasted peanuts was found to be better and uniform as compared to the conventionally roasted peanuts. The generation of roasted aroma though, observed good in conventionally roasted ones but found to be more prominent and pleasant in microwave and IR roasted peanuts. The texture of microwave and

Table 6: Changes in fatty acid composition of conventional, microwave and IR roasted pea nuts (n=3)

Fatty acids (%)	Raw	Conventional	Microwave	IR
Palmitic $C_{16:0}$	10.78±0.23^{a}	15.26±0.19^{c}	14.11±0.20^{b}	14.54±0.14^{b}
Stearic $C_{18:0}$	2.83±0.09^{a}	5.49±0.04^{c}	4.45±0.19^{b}	4.80±0.03^{b}
Oleic $C_{18:1}$	41.72±0.22^{c}	35.66±0.22^{a}	38.40±0.16^{b}	38.21±0.18^{b}
Linoleic $C_{18:1}$	34.03±0.10^{d}	30.40±0.16^{a}	32.33±0.10^{c}	32.00±0.15^{b}
Linolenic $C_{18:2}$	1.91±0.03^{d}	0.80±0.04^{a}	1.23±0.05^{c}	1.10±0.05^{b}
Arachidic $C_{20:0}$	1.15±0.18^{a}	1.59±0.10^{c}	1.30±0.09^{b}	1.41±0.12^{b}
SFA	14.76±0.17^{a}	22.34±0.11^{d}	19.86±0.16^{b}	20.75±0.18^{c}
MUFA	41.72±.22^{c}	35.66±0.22^{a}	38.40±0.10^{b}	38.21±0.18^{b}
PUFA	35.94±0.07^{d}	31.20±0.10^{a}	33.56±0.07^{c}	33.10±0.10^{b}

Values with different superscripts in columns differ significantly (p≤0.05); Values with mean± SD.

Table 7: Changes in sensory attributes of conventional, microwave and IR roasted pea nuts (n=3)

Roasting methods	Colour	Aroma	Taste	Texture	Over all acceptability
Raw	7.48±0.12^{a}	6.89±0.10^{a}	7.08±0.22^{a}	6.89±0.09^{a}	7.12±0.24^{a}
Conventional	7.70±0.04^{b}	7.45±0.12^{b}	7.50±0.11^{b}	7.59±0.16^{b}	7.53±0.22^{b}
Microwave	7.89±0.04^{c}	7.88±0.10^{c}	8.12±0.28^{c}	8.19±0.22^{c}	7.90±0.11^{c}
Infrared	7.91±0.08^{c}	7.77±0.09^{c}	8.04±0.06^{c}	8.10±0.19^{c}	7.82±0.05^{c}

Values with different superscripts in columns differ significantly (p≤0.05); Values with mean± SD.

IR roasted peanuts were more crisp and crumble in comparison to the conventionally roasted ones, which is one of the important quality characteristics of roasted products. Conventionally roasted peanuts received an overall acceptability score of 7.53 on a 9 point Hedonic scale while microwave and IR roasted pea nuts received a score of 7.90 and 7.82, respectively. Over all, microwave and IR roasted samples received better sensory scores in comparison to conventionally roasted ones.

CONCLUSION

Roasting of peanuts by conventional methods caused more oxidative changes than those roasted by microwave and IR methods. Conventional roasting had slightly darkened the seeds in comparison to other two methods of roasting. Peanut skin exhibited relatively higher amounts of both phenolics and flavonoids than their kernel counterparts and roasting by all the methods enhanced them slightly. Fatty acids underwent higher rate of degradation when roasted using conventional methods than other methods. Both microwave and IR roasting of peanuts received better overall acceptability score than conventionally roasted samples. Therefore, keeping in view, the physico-chemical and sensory changes occurred during all the three methods of roastings, it can be concluded that a high temperature short time roasting process using microwave and IR can be used as an efficient and attractive alternative methods to conventional roasting with less deterioration in their quality attributes.

ACKNOWLEDGEMENTS

Authors greatly acknowledge Head, FVT division for providing the facility for carrying out colour measurement of the product.

REFERENCES

Adu, O.B., Ogundeko J.O., Oguninola, O.O., Saiba, G.M. and Elemo. B.O. 2015. The effect of thermal processing on protein quality and free amino acid profile of *Terminalia catappa* (Indian almond) seeds. *J. Food. Sci. Technol.*, **52**(7): 4637-4641.

AOAC. 1984. Official methods of analysis. Association of official Analytical chemists.14th edition, Arlington, Virginia.

AOCS. 1990. Official methods and recommended practices of American Oil Chemical Society. 4th edition, Champaign IL.

Asibuo, J.Y., Arkzomah, R., Safo-kantanka, O. and Adu-Dapaah, H.K. 2008. Evaluation of nutritional quality of Ground nuts (*Arachis hypogaea* L) from Ghana. *African. J. Food. Agric. Nutrn. Devpt.*, **8**(2): 134-141.

Buckholz, J.R., L.L Daun, H. Stier, E. and Trout, R. 1980. Influence of roasting time on sensory attributes of fresh roasted peanuts. *J. Food Sci.*, **45**(3): 547-554.

Driscoll, R.H. and Madamba, P.S. 1994. Modelling the browning kinetics of garlic. *Food Australia*, **46**(2): 66–71.

El-Badrawy, E.E.Y, El-zainy, A.R.M. Shalaby, A.O and El-Sayed, N.Y. 2007. Effect of microwave roasting on chemical composition of peanut seeds and comparing it with the ordinary roasting process. In: 12th conference of faculty of specific education, pp 11-12.

Fakhriya, S.T. Suzanne, M.W and Fatima, A. 2012. Comparison between anti-oxidant activities of phenolic extract from different parts of peanut. *Life Sci. J.*, **9**(2): 207-215.

Francisco, M.L.D.L and Resurrection, A.V.A. 2008. Functional components in peanuts. *Cri. Rev. Food. Sci. Nutrn.*, **48**(8): 715-746.

Jia, Z. Mencheng, T. and Wu, J. 1999. The determination of flavonoid contents in mulberry and their scavenging effects on superoxide radicals. *Food Chem.*, **64**(4): 555-559.

Khan, M.A. Semwal, A.D. Sharma, G.K. Yadav, D.N. and Srihari, K.A. 2008. Studies on the development and storage stability of groundnut (*Arachis hypogaea*) burfi. *J. Food. Quality.*, **31**(5): 612-626.

Krishnamurthy, K., Khuarana, H.K., Jun, S., Irudayaraj, J. and Demiric, A. 2008. Science and Food Safety: Infrared heat in food processing, an overview. Comp. *Rev. Food. Sci. Technol.*, **7**(1):1–12.

Larmond, E. 1977. Laboratory method for sensory evaluation of food. Publication no 1637, Canadian Dept of Agric. Ottawa, Canada, pp 12-16.

Makinde, F.M. and Oladunni, S.S. 2016. Effects of processing on nutritional quality of raw almond (*Terminalia catappa Linn*) kernels. *Adv. Appl. Sci. Res.*, **7**(1): 1-7.

Mar Win, Azizah Abdul–Hamid, Bablishah Baharin, Farooq Anwar, Madumpal C. Sabu and Mohd S. Pak Dek. 2011. Phenolic compounds and antioxidant activity of peanuts skin, hull, raw kernel and roasted kernel of flour. *Pak. J. Bot.*, **43**(3): 1638-1642.

Meilgaard, M. Civelle, G.V. and Carr, B.T. 1990. Affective tests consumer tests in-house panel acceptance tests. In sensory evaluation techniques, Meilgaard, M. Civelle, G.V and Carr B.T (Eds). CRC Press, FL, USA., pp. 231-263.

Montavon, P. Mauron, A.F. and Duruz, E. 2003. Changes in green coffee protein profiles during roasting. *J. Agric. Food. Chem.,* **51**(8): 2335–2343.

Murkovic, M. Piironen, V. Lampi, A.M. Kraushofer, T. and Sontag. G. 2004. Changes in chemical composition of pumpkin seeds during the roasting process for production of pumpkin seed oil (Part 1, Non-volatile compounds). *Food Chem.,* **84**(3): 359–365.

Nielsen, S.S. 1991. Digestibility of legume protein. *J Food Technol.,* **45**: 112-118.

Ozdemir, M. and Deveres, O.Y. 1999. The thin layer drying characteristics of hazelnuts during roasting. *J. Food Engg.,* **42**(4): 225-233.

Rosenberg, U. and Boggle, K.W. 1987. Microwave thawing, drying and baking in the food industry. *Food Technol.,* **8**: 291-298.

Villamiel, M. Fardino, R.L. Corza, N, Castro, M. Olano, A. Rosina, L.F. and Isabel, M.C. 1996. Effect of continuous flow of microwave treatment on chemical and microbiological characteristic of milk. *Zeitschirift fur Lebensmittel-Untersuchung Und Forschung,* **202**(1): 15-18.

Sanders T.H. 2002. Groundnut (peanut oil) In: Vegetable oils in Food Technology Composition, Properties and Uses (FD Gunston ed). Blackwell publications. Oxford.

Scalbert, A. Manoch, C. Morand, C. and Remesy, C. 2005. Dietary poly-phenols and the prevention of diseases. *Cri. Rev. Food Sci. and Nutrn.,* **45**(4): 287-306.

Singleton,V.L., Orthofer, R. and Lamuel-Raventos, R.M. 1999. Analysis of total phenols of other oxidation substrates and antioxidants by means of Folin-Ciocalteau reagent. *Methods in Enzymology,* **299**: 152-178.

Yoshida, H. Mirooka, B.N. and Kajimoto, G. 1990. Microwave energy effects on quality of some seed oils. *J. Food Sci.,* **55**(5): 1416-142.

Yuan, X. Wang, J. and Yao, H. 2005. Antioxidant activity of feruloyl oligosaccharides from wheat bran. *Food Chem.,* **90**(4): 759-764.

Yvonne, C. Walker, L. Vogler, B. and Verghese, M. 2007. Changes in the phyto-chemical composition and profiles of raw, boiled and roasted peanuts. *J. Agric. Food Chem.,* **55**(22): 9266-9273.