Original article

Composition, stability and acceptability of different vegetable oils used for frying peanuts

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Summary The purpose of this work was to determine the chemical stability of vegetable oils in the frying process and the consumer acceptance of fried-salted peanuts prepared in different vegetable oils. Fatty acids composition was determined in sunflower, corn, soybean, peanut and olive oils. A chemical study (free fatty acid and *p*-anisidine values) of these oils at frying temperature (170 °C) was developed during 96 h. Consumer test of fresh products was performed on fried-salted peanuts prepared in the different oils. Peanut oil and virgin olive oil presented oleic acid as predominant fatty acid (44.8% and 64.2%, respectively), making it more resistant to lipid oxidation at frying temperature than the other refined vegetable oils (sunflower, corn and soybean oils). Virgin olive and peanut oils showed less increment of free fatty acids and *p*-anisidine value than the other oils along the heating essay. In addition, fried-salted peanuts prepared with refined peanut oil showed higher consumer acceptance than those prepared with other vegetable oils such as sunflower, corn, soybean and olive oils. Peanut oil could be used to fry peanuts obtaining products with higher consumer acceptance and shelf-life, thus preventing loss of their sensory and nutritional quality.

Keywords Consumer acceptance, free fatty acids, fried peanuts, oxidative stability, *p*-anisidine value, vegetable oils.

Introduction

Oxidative rancidity is the most important complex of chemical reactions that limits the shelf life of oils (Kristott, 2000). These reactions imply the development of various off-flavours and off-odours, which render foods unacceptable or reduce their shelf life. In consequence, the oxidative stability remains as an important parameter in evaluating the quality of fats and oils (Warner & Eskin, 1995; Hidalgo *et al.*, 2002).

Peanuts contain high percentages of oil (50–55%) and protein (25–28%) and low percentages of carbohydrates and ashes (Grosso & Guzman, 1995). A large proportion of peanut production in the world goes into domestic food use, the end products being peanut butter, salted peanut products, confections and roasting stock. These peanut-containing foods enjoy widespread popularity because of their unique roasted peanut flavour. The rest of the peanut production is utilised as edible oil source of high quality. Peanuts are continually applied for preparation of new and improved food products (Ahmed & Young, 1982).

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In general, peanut oil contain approximately 30–35% and 45–50% of linoleic and oleic acids, respectively, which becomes susceptible to development of rancid and off-flavours through lipid oxidation (St. Angelo, 1996). Although, peanut oil is one of the most stable vegetable oils to oxidation in comparison with other vegetable oils like soybean. This is partly because of the fatty acid composition, which is low in 18:3ω 3 (O'Keefe *et al.*, 1993; St. Angelo, 1996). The rates of oxidation of C18 unsaturated fatty acids are approximately 1:10:20 for oleic (18:1), linoleic (18:2) and linolenic (18:3), respectively (Nawar, 1993). Fatty acid composition appears important in determining oxidative stabilities but other factors are also involved, such as the presence of antioxidant and pro-oxidant compounds. The effect of fatty acid composition on oxidative stability of oil has been studied by a number of investigators (Liu & White, 1992; O'Keefe *et al.*, 1993; Bolton & Sanders, 2002).

Many factors influence the shelf life of peanuts products. These include variety, maturity at harvest, market grade and seed size, processing methods and storage conditions (temperature, time, light and exposure to oxygen). Deep frying is one of the methods of food preparation used both in the home and in industry. Fried foods are highly palatable because of their fat

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content and the development of unique flavours and aroma. Fried-salted peanuts had higher overall acceptance than roasted peanuts (Grosso & Resurreccion, 2002; Nepote *et al.*, 2004, 2006). However, the frying oil changes substantially in its chemical and physical properties after prolonged use. A great number of volatile and non-volatile products are produced during deep frying of oil by thermal degradation of free fatty acid (FFA). These acids are formed by triglyceride hydrolysis or by oxidation of aldehydes. The increase of these components can be monitored by means of FFA and *p*-anisidine values (p-AV). Peroxides formed at elevated temperatures fragment immediately with formation of hydroxyl compounds. Therefore, determination of peroxide values to evaluate the quality of oil in deep frying is not appropriate. The most important factor determining the quality of the fried food is the quality of the oil used for frying it. The use of more stable oil to elaborate fried peanuts would increase shelf-life and improve the oxidative stability of peanut products, thus preventing loss of sensory and nutritional quality (Warner *et al.*, 1997; Bolton & Sanders, 2002).

The objective of this work was to determine the chemical stability of vegetable oils at frying temperature and the consumer acceptance of fried-salted peanuts prepared in different vegetable oils.

Material and methods

Materials

Refined sunflower and soybean oils were obtained from Aceitera General Deheza, S.A. (General Deheza), refined peanut oil from Nutrin S.A. (Ticino), refined corn oil from Arcor S.A. (Arrollito) and virgin olive oil from Exprodar S.A. (Cruz del Eje). All of these companies are from Córdoba, Argentina.

Sound and mature seeds of peanuts (*Arachis hypogaea* L.) type Runner, size 38/42 kernels per oz (2004 crop) were provided by the company, Lorenzati, Ruescht y Cia of Ticino, Cordoba, Argentina. Before processing, peanuts were inspected; damaged and bruised kernels were manually removed.

Fatty acid composition of vegetable oils

Fatty acid methyl esters were prepared on vegetable oils used for frying peanuts: sunflower, corn, soybean, peanut and olive oils by transmethylation (Jellum & Worthington, 1966; Grosso *et al.*, 2000). The fatty acid methyl esters of total lipids were analysed on a Hewlett Packard HP-6890 gas-liquid chromatograph (Palo Alto, CA, USA) equipped with a flame ionisation detector (FID HP-3398). An HP-INNO-Wax capillary column (30 m × 0.32 mm × 0.5 nm, with polar polyethylene glycol, Hewlett Packard, Santa Clara, CA, USA) was used. The separated fatty acid methyl esters were identified by comparing their retention times with those of authentic samples, which were purchased from Sigma Chemical Co. (Sigma Chemical Co, St. Louis, MO, USA). Quantitative fatty acids analysis was performed using heptadecanoic acid methyl ester as internal standard. Iodine values (IV) were calculated from fatty acid composition (Hashim *et al.*, 1993) using the following formula: IV = (% oleic × 0.8601) + (% linoleic × 1.7321) + (% eicosenoic × 0.7854).

Oil heating essay

Two litres of each vegetable oil: sunflower (S), corn (C), soybean (So), peanut (P) and olive (O) oil were heated in a domestic fryer (Moulinex, Supralys Model, China) and left during 96 h at 170 °C (frying temperature). Samples (10 mL of oil) were taken each 12 h and analysed for FFA and p-AV.

Free fatty acid value

It was evaluated following the AOAC method 14.070 (AOAC, 1980) using 5 g oil of each sample obtained from the heating essay. The FFA was expressed as % p/p oleic acid in the oil sample.

p-Anisidine value

This is a spectrophotometric method commonly used as a measurement for lipid oxidation products. The procedure was described by IUPAC (1987). The absorbance of solutions were measured at 350 nm in a spectrophotometer: UV-V Diode Array Spectrophotometer Hewlett Packard HP 8452 A (Palo Alto, CA, USA) using *n*-hexane as blank. The *p*-anisidine reagent was from BDH Laboratory Reagents, (Poole, England). The p-AV was given by the formula: p-AV = 25 × (1.2As-Ab) m^{-1}, where 'As' is absorbance of the fat solution (oil and *n*-hexane) after reaction with the p-AV reagent, 'Ab' the absorbance of the fat solution and '*m*' the mass of the oil in grams.

Product elaboration: fried-salted peanuts prepared in different vegetable oils

Peanuts were fried at 170 °C in 2 L of fresh sunflower (FP-S), corn (FP-C), soybean (FP-So), peanut (FP-P) and olive (FP-O) oils in a domestic fryer (Moulinex, Supralys Model, China). Before the frying procedure the oils were heated until 170 °C. After that, peanuts (1 kg) were added into oil and fried during 4 min. The same experiment was repeated in three replicates. Peanuts were heated to a medium roast or an average Hunter Color Lightness (*L*) value of 50 ± 1.0 (Johnsen *et al.*, 1988). Fried peanuts were salted with analytical grade sodium chloride (Laboratorios Cicarelli, San Lorenzo, Santa Fe, Argentina).

In the final products, the moisture content was 2% according to previous unpublished results evaluated following AOAC methods (AOAC, 1980). After preparation, samples were packaged in 27 × 28 cm plastic bags (Ziploc, Johnson & Son, Buenos Aires, Argentina). The samples were stored in freezer (−18 °C) until analysis.

Determination of oil, ash, protein and carbohydrate contents of the peanut samples

Three samples (5 g) from each peanut product were examined for moisture, lipids, protein, ash and carbohydrates. The seeds were selected at random. Seeds were milled and oil was extracted for 16 h with *n*-hexane in a Soxhlet apparatus. The extracted oils were dried over anhydrous sodium sulphate, and the solvent was removed under reduced pressure in a rotary film evaporator. Lipid percentage was determined by weight difference. Ash and nitrogen contents were determined according to the AOAC (1980) methods. Ash was performed by incineration in a muffle furnace at 525 °C. The nitrogen content was estimated according to the Kjeldahl method and converted to protein percentage by using the conversion factor 5.46 (AOAC, 1980). Carbohydrate content was estimated by difference of the other components using the following formula: carbohydrate content = 100% − (% protein + % oil + % ash).

Consumer analysis

Panelists ($n = 100$) were from Cordoba (Argentina) and were recruited using the following criteria: age between 18 and 65, non-smokers, non-food allergies and eat roasted peanuts and/or peanut products at least twice per week. For sample evaluation, 5 g of the peanut samples were placed into plastic cups with lids, coded with three digit random numbers. Samples consisting of FP-S, FP-C, FP-So, FP-P and FP-O (three replications of each one) were presented to each panelist in random order during the test day. Samples were presented with water and paper ballots on a plastic tray. Panelists were instructed to consume the whole sample and rinse their mouths with water between samples to minimise any residual effect. A 7-point hedonic scale ranging from 1 = dislike very much to 7 = like very much was used to evaluate acceptance for the attributes of colour, aroma, texture and flavour from the samples (Meilgaard *et al*., 1991).

Statistical analysis

The data were analysed using the InfoStat software, version 1.1 (Facultad de Ciencias Agropecuarias, Universidad Nacional de Cordoba, Argentina). Mean and SD were calculated. Analysis of variance was used to detect significant differences between samples from consumer and chemical analyses using Duncan tests to find significant differences ($\alpha = 0.05$) between mean. Pearson coefficient was used to calculate correlation between dependent variables (the fatty acid composition and the increment rates of FFA and p-AV during heating essay of the vegetable oils). Second order polynomial regression equations in the regression analyses were used to determine if the independent variables (time) had an effect on the chemical indicators (FFA and p-AV).

Results and discussion

Fatty acid composition of the different vegetable oils

The fatty acid percentages, oleic/linoleic ratio (O/L), saturated/unsaturated ratio (S/U) and IV of refined vegetable oils: sunflower, corn, soybean, peanut, and virgin olive oil are presented in Table 1.

As expected, virgin olive and peanut oils had oleic acid as the major fatty acid. On the contrary, the major fatty acid in sunflower, corn and soybean was linoleic acid.

Sunflower oil resulted with significantly lower S/U ratio than the other vegetable oils. The sunflower oil showed high IV without significant differences in comparison with corn and soybean oils. Lower IVs were obtained in olive and peanut oils without significant differences between them.

In addition, sunflower and soybean oils showed lower O/L ratio than the other oils. The highest O/L ratio was found in virgin olive oil followed by peanut oil and corn oil with significant differences among these oils.

Other authors (Hidalgo *et al*., 2002) found similar fatty acid composition in the same vegetable oils from other origins.

Heating essay

The changes in the chemical indicators: FFA and p-AV during heating process (170 °C) of vegetable oils: sunflower, corn, soybean, peanut and olive are shown in the Fig. 1. The chemical indicators increased with time at frying temperatures in all vegetable oils.

Along the time of the essay, virgin olive oil had higher FFA with significant differences ($\alpha = 0.05$) with respect to the other refined vegetable oils. Refined oils showed little significant differences.

Free Fatty Acid values obtained of each vegetable oils were from 0.02 (0 h) to 0.62 (96 h) in sunflower, from 0.06 (0 h) to 0.65 (96 h) in corn, from 0.04 (0 h) to 0.53 (96 h) in soybean, 0.07 (0 h) to 0.59 (96 h) in peanut and from 0.50 (0 h) to 0.91 (96 h) in olive. These results showed that olive oil presented a significantly lower increment of FFA in comparison with the other vegetable oils. The highest increment was detected in sunflower oil and in corn oil. In the middle were soybean

Table 1 Fatty acid percentages (g/100 g fatty acids), oleic/linoleic ratio (O/L), saturated/unsaturated ratio (S/U) and iodine value (IV) of vegetable oils: sunflower, corn, soybean, peanut, and olive oils

	Vegetable oils[a]				
Fatty acids	Sunflower	Corn	Soybean	Peanut	Olive
Saturated					
Palmitic acid, 16:0	5.90 ± 0.60 A	12.30 ± 1.30 C	11.90 ± 1.30 C	9.50 ± 1.10 B	16.70 ± 1.60 D
Stearic acid, 18:0	3.90 ± 0.30 B	2.30 ± 0.21 A	4.60 ± 0.50 C	2.50 ± 0.20 A	2.00 ± 0.10 A
Arachidic acid, 20:0	0.40 ± 0.01 A	0.70 ± 0.03 B	0.50 ± 0.06 A	1.20 ± 0.12 C	0.50 ± 0.07 A
Behenic acid, 22:0[b]	Tr.	Tr.	Tr.	2.80 ± 0.30	Tr.
Lignoceric acid, 24:0[b]	Tr.	Tr.	Tr.	1.60 ± 0.20 C	Tr.
Monounsaturated					
Oleic acid, 18:1 (9)	25.40 ± 2.31 A	34.8 ± 3.8 B	22.00 ± 2.40 A	44.80 ± 4.30 C	64.22 ± 6.60 D
Eicosenoic acid, 20:1 (11)	0.40 ± 0.02 A	0.40 ± 0.10 A	0.50 ± 0.10 A	1.80 ± 0.19 B	0.40 ± 0.02 A
Poliunsaturated					
Linoleic acid, 18:2 (9,12)	62.50 ± 6.11 D	47.95 ± 4.60 C	52.50 ± 5.50 C	35.50 ± 3.70 B	15.00 ± 1.72 A
Linolenic acid, 18:3 (9,12,15)	0.25 ± 0.03 A	0.90 ± 0.10 B	7.10 ± 0.70 C	0.30 ± 0.04 AB	0.90 ± 0.09 B
O/L ratio	0.41 ± 0.01 A	0.73 ± 0.1 B	0.42 ± 0.00 A	1.26 ± 0.01 C	4.28 ± 0.1 D
S/U ratio	0.13 ± 0.00 A	0.18 ± 0.0 B	0.22 ± 0.00 B	0.21 ± 0.00 B	0.23 ± 0.0 B
IV	130.38 ± 12.57 C	113.30 ± 11.31 BC	110.25 ± 11.63 BC	101.44 ± 10.25 AB	81.53 ± 8.65 A

[a]Mean ± SD followed by the same letter within each row are not significantly different at $\alpha = 0.05$.
[b]Tr. = trace value (<0.3%).

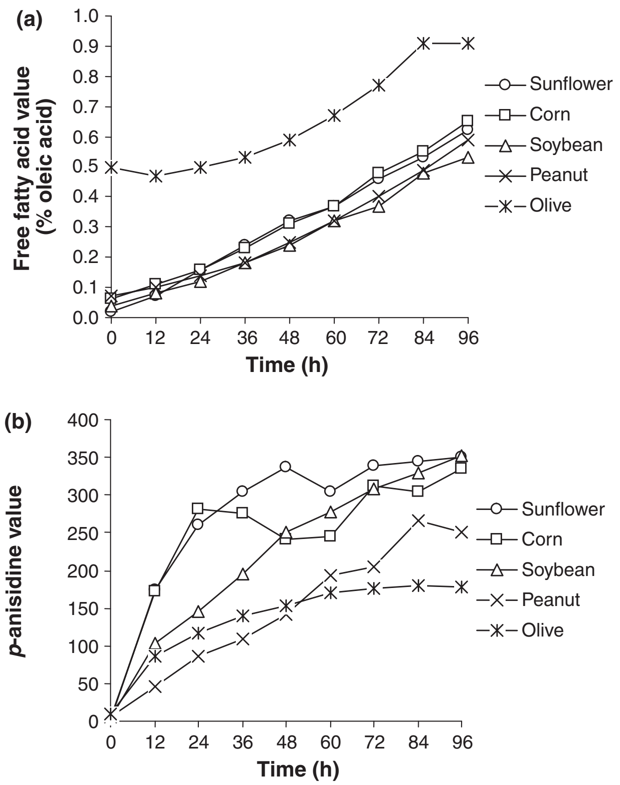

Figure 1 Results from the chemical analyses: (a) free fatty acid value and (b) *p*-anisidine value during the heating process at 170 °C (frying temperature) of vegetable oils: sunflower, corn, soybean, peanut and olive oils.

and peanut oils with significant differences between them.

p-Anisidine values obtained of each vegetable oils were from 1.88 (0 h) to 349.43 (96 h) in sunflower, from 3.14 (0 h) to 335.57 (96 h) in corn, from 3.52 (0 h) to 351.78 (96 h) in soybean, 4.81 (0 h) to 251.35 (96 h) in peanut and from 8.81 (0 h) to 177.49 (96 h) in olive. According to these results, corn, sunflower and soybean oils showed significantly higher increment of p-AV than the other vegetable oils, without significant differences between them. The lowest increment of p-AV was detected in olive oil followed by peanut oil, with significant differences between them. These FFA and p-AV increments were related to the IV with Pearson correlation coefficients higher than 0.80. Thus, when IV was high (sunflower, corn and soybean), the vegetable oil stability was low as high increment of FFA and p-AV were obtained.

It has been reported a high level of polyunsaturated fatty acids such as linoleic and linolenic acids decreased the oil stability under oxidation conditions making them susceptible to the development of oxidised compounds and off-flavours (St. Angelo, 1996; Warner *et al.*, 2001; Hidalgo *et al.*, 2002).

Hidalgo *et al.* (2002) found oil stability variation in the oils depended on the fatty acid composition as well as on the presence of different minor components in the oils. In that work, the virgin olive oil resulted with high stability in comparison with other refined vegetable oils. This was correlated with the fatty acid composition and the presence of natural antioxidants (phenol and tocopherol content).

During the frying process, vegetable oil is superficially adsorbed by the fried peanuts. It would imply a change in fatty acid composition of the final product with respect to raw peanuts as it was found by Bolton & Sanders (2002). They found O/L ratios of 27.9 in high-oleic peanuts fried in high-oleic peanut oil and of 13.6 in high-oleic peanuts fried in conventional peanut oil. As a consequence, it would be better to use saturated and monounsaturated frying oils to prepare fried-salted peanuts and to provide better stability to the end products (Warner *et al*., 1997; Neff *et al*., 2000; Warner *et al*., 2001; Bolton & Sanders, 2002; Nepote *et al*., 2006). Bolton & Sanders (2002) determined the full potential for shelf-life improvement of high-oleic peanuts oil to roast peanuts in comparison with conventional peanut oil. They found that peanuts roasted in high-oleic peanut oil had a shelf-life of almost two times than those roasted in normal peanut oil. Warner *et al.* (1997) studied the effect of fatty acid composition of oils on flavour and stability of fried foods such as potato chips. They reported that high-oleic sunflower oil (78% oleic acid) produced the lowest levels of total polar compounds and the lowest hexanal and pentanal, indicating greater frying oil stability and oxidative stability of the food in comparison with cotton seed oil (16%oleic/55%linoleic). According to the results observed in this work, the olive and peanut oils showed more oxidative stability and they could be better in the preparation of fried food.

Regression coefficients and R^2 of FFA and p-AV from the chemical analyses during the heating process at 170 °C (frying temperature) of vegetable oils: sunflower, corn, soybean, peanut and olive oils are presented in the Table 2.

The dependent variables (FFA and p-AV) showed $R^2 > 0.75$ in all vegetable oils (S, C, So, P and O) indicating these variables are good predictors. Therefore, these regression equations could be used to predict the effect of time at frying temperature (170 °C) on the stability (measured with the chemical variables FAA and p-AV) of the studied vegetable oils.

In the Food Code from Argentina, 0.3% and 1.0% as oleic acid are the maximum levels of FFAs allowed for refined oils and virgin olive oil, respectively, to be used in frying process. Using the prediction equation, FFA higher than 0.3% were reached after 46.8 h in S, 47.7 h in C, 58.4 h in So and 57.1 h in P oil at 170 °C. In the case of virgin olive oil, the time to reach a FFA of 1.0% was 99.8 h at 170 °C. In consequence, virgin olive oil had around two times longer stability at frying temperature than the other refined vegetable oils. Peanut and soybean oils had higher stability than sunflower and corn oils.

Determination of oil, protein, ash and carbohydrate contents of the peanut samples

In general, the peanut fried in different vegetable oils did not showed significant differences ($\alpha = 0.05$) in oil, protein, carbohydrate and ash contents. The average percentages (on dry basis) of oil, proteins, carbohydrates and ashes were 52.2, 23.1, 21.1 and 3.6, respectively. Considering an average 48–50% of initial oil in peanuts, the absorbed oil in the final product was between 2.2–4.2%, independently of the vegetable oil used in the frying process.

Consumer analysis

For preparing fried-salted peanuts, it is important to consider the oil stability during the frying process and the consumer acceptance of the product. Then, it was determined the stability of the oils at frying temperature in the first part of this study to discuss which oil is better during the frying process. In the second part, it was performed a sensory analysis to know the consumer opinion about the acceptability of fried-salted peanuts.

Table 2 Regression coefficients and R^2 of free fatty acid and *p*-anisidine values from the chemical analysis during the heating process at 170 °C (frying temperature) of vegetable oils: sunflower, corn, soybean, peanut and olive oils

		Regression coefficients[a]			
Dependent variable	Vegetable oil	β_o	β_1	β_{11}	R^2
Free fatty acid value	Sunflower	0.013273	0.005983	0.000003	0.997812
	Corn	0.057212	0.004044	0.000022	0.998532
	Soybean	0.035758	0.003359	0.00002	0.996165
	Peanut	0.069939	0.001975	0.000036	0.999708
	Olive	0.475818	0.000164	0.000051	0.96744
p-Anisidine value	Sunflower	46.223939	8.936623	−0.063321	0.918989
	Corn	67.656485	6.477957	−0.042110	0.764375
	Soybean	15.511697	6.117827	−0.027830	0.994535
	Peanut	3.846545	3.411697	−0.007044	0.981284
	Olive	24.316606	4.133780	−0.027128	0.971576

[a]Regression coefficients for the general regression equation: $Y = \beta_o + \beta_1 X + \beta_{11} X^2$, where Y = dependent variable (free fatty acid value and *p*-anisidine value) and X = independent variable (time in hours at 170 °C).

Fried-salted peanuts	Consumer acceptability by attribute[a]			
	Colour	Aroma	Texture	Flavour
FP-S	5.12 ± 0.86 B	4.90 ± 1.17 B	5.22 ± 1.07 B	5.63 ± 1.01 C
FP-C	4.86 ± 1.05 A	4.43 ± 1.22 A	4.99 ± 1.11 A	5.13 ± 1.31 B
FP-So	5.13 ± 1.06 B	4.33 ± 1.23 A	4.91 ± 1.14 A	4.85 ± 1.36 A
FP-P	5.37 ± 1.02 C	5.36 ± 1.03 C	5.39 ± 1.08 B	5.98 ± 0.93 D
FP-O	5.04 ± 1.11 B	4.33 ± 1.30 A	4.93 ± 1.22 A	5.03 ± 1.54 AB

[a]Mean ± SD followed by the same letter within each column are not significantly different at $\alpha = 0.05$.

Table 3 Average of consumer acceptability by attribute of fried-salted peanuts in different vegetable oils: sunflower (FP-S), corn (FP-C), soybean (FP-So), peanut (FP-P) and olive (FP-O)

Averages of consumer acceptability by attribute of peanuts fried in different vegetable oils: S, C, So, P and O are shown in Table 3. Significant differences ($\alpha = 0.05$) from the consumer acceptance for each attribute among the products: fried-salted peanuts in vegetable oils (FP-S, FP-C, FP-So, FP-P and FP-O) were found. In texture, FP-P had similar consumer acceptance than FP-S (5.39 and 5.22, respectively), without significant differences between them but higher than the other products. Fried peanuts in peanut oil (FP-P) had the highest consumer acceptances for colour (5.37), aroma (5.36) and flavour (5.98) in comparison with FP-S, FP-C, FP-So and FP-O. In general, the products had consumer acceptances of about '5 = like moderately' in a hedonic scale of seven points. In other works (Nepote *et al.*, 2006), fried-salted peanut had overall acceptance near seven (like moderately) in a hedonic scale of nine points.

The consumer acceptance test gives an estimate of product acceptance based on the product's sensory properties. The preference of food product includes the choice of one sample over others. Preference is implied from consumer acceptance test using hedonic scale ratings (Resurreccion, 1998). Therefore, there is an obvious and direct relationship between measuring product liking/acceptance and preference. The obtained results of overall consumer acceptance in this study are indicating the preference trend of the consumer on fried-salted peanuts using different vegetables oils.

Unsaturated fatty acid emulsified in water tasted bitter with a relativity low threshold value for α-linolenic acid (Belitz & Grosch, 1999). In the present work, the soybean oil showed higher linolenic acid and it also showed lower acceptance in the consumer test. The proportion of the linolenic fatty acid presented high negative correlation (−0.77) with consumer acceptance of fried peanuts prepared with different vegetable oils.

Conclusions

The virgin olive oil showed higher oleic acid content and better oxidative stability. However, fried-salted peanuts prepared with refined peanut oil had higher consumer acceptance than those prepared with other vegetable oils such as S, C, So and O-oils. Peanut oil also had high percentages of monounsaturated fatty acids (oleic) making it more resistant to lipid oxidation at frying temperature, as was observed in the p-AV reached during oil heating essay. In conclusion, peanut oil could be used to fry peanuts obtaining products with high consumer acceptance and shelf-life, thus preventing loss of their sensory and nutritional quality.

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