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THE EFFECT OF HARVESTING TIMES ON OIL AND FATTY ACID COMPOSITION OF PEANUT VARIETIES GROWN IN MAIN CROPPED CONDITION IN CUKUROVA REGION *(MEDITERRANEAN AREA)* IN TURKEY

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Abstract
This study was conducted at the experimental area of the Department of Field Crops, Faculty of Agriculture, Cukurova University as a main crop in 2015. The objective of this study was to determinate the effect of harvesting dates on oil and fatty acid composition of peanut (*Arachis hypogaea L.) varieties grown in main cropped condition in Cukurova region.* The experimental design was a split plot with three replications. The Halisbey, Sultan, Arioglu-2003, Osmaniye-2005, NC-7, Batem-5025, Flower 22, Flower-32, Flower-36, Brantley and Wilson peanut varieties (Virginia market type) were used as a plant material in this research. The plants were harvested at 149, 156, 163 and 170 days after sowing (DAS). Oil and fatty acids (palmitic acid, stearic acid, oleic acid, linoleic acid, linolenic acid, arachidic acid, behenic acid and lignoceric acid) content and Oleic acid to Linoleic acid ratio (O/L) of peanut varieties were investigated. As a result, the oil percentage of peanut varieties was increased from 47.8% to 50.3% when the harvesting delayed from 149 DAS to 170 DAS. While the palmitic and linoleic acid percentage was decreasing, the stearic and oleic acid percentage was increased when the harvesting delayed from 149 DAS to 170 DAS in peanut varieties. The others fatty acids were not affected by the harvesting time.

Keywords: Peanut, main crop, harvesting time, oil content, fatty acid.

Introduction

Peanut (*Arachis hypogaea* L.) is the fourth major oilseeds crop of the world next to soybean, rapeseed and cotton. Peanut contributes 8.7% of the total oil seeds production (45 million ton) in the world in 2015 (FAO, 2015). About two-thirds of total peanut production is crushed for oil and the remaining one-third is used in confectionery products in the world (Dwivedi et al. 1996). Peanut oil accounted for 3.0% of the world's vegetable oil production in 2015. For this reason, peanut is an important oilseed crop for vegetable oil production. Peanut seeds contain 35-56% oil and 25-30% protein and 9.5-19.0% carbohydrate on a dry seed basis. In addition, they are a good source of mineral (P, Ca, Mg and K) and vitamins (E, K and B group). For this reason, it is an important source of edible oil and protein for human nutrition. Peanuts are also a cheap source of protein, a good source of essential vitamins and minerals, and a component of many food products (Ingale and Shrivastava, 2011; Chamberlin et al. 2014 and Chowdhury et al. 2015). Ishag (2000) and Kaba et al. (2014) reported that peanut has indeterminate growth habit. For this reason, flowering and pod formation continue long time during the growing period. The peanut plants produced many flowers (18-142 flowers plant^{-1}) but, only 15-20% of flowers produce mature pods (Lim and Hamdan, 1984). Young et al. (1982) reported that total pod production continually increased with growth period, but that harvested yield reached a peak and then decline due to increased field losses at the longer period. Oil content is an important quality characteristic in peanut seed. The oil content of peanut seed influences by genotypic variation, growing conditions and maturity. Court et al. (1984), Sattayarak (1997), Lu et al. (1997) and Canavar and Kaynak (2013) reported that oil content was increased by delaying the harvesting times. Andersen and Gorbet (2002) and Chowdhury et al.

(2015) reported that the nutritional and storage quality of peanut are determined by its fatty acids composition. Young and Worthington (1974), Dwivedi et al. (1996) and Isleib et al. (2008) reported that fatty acid composition of peanut seed oil influenced by varietal and seasonal variation, genotypic variation, air and soil temperature, planting date, soil nutrient, growing conditions and maturity. The amount of saturated and unsaturated fatty acids in peanut oil varies from 10.92% to 17.47% and from 81.13% to 94.81% respectively. The major fatty acids components are oleic acid, linoleic acid and palmitic acid in peanut oil. Peanut oil is rich in oleic and linoleic acids. Oleic acid content in peanut genotypes can vary from 21 to 85% and linoleic acid from 2 to 43%. Andersen and Gorbet (2002) and Gulluoglu et al. (2016a) reported that, seed maturity can also influence the fatty acid composition of peanut. In general, oleic acid increases and linoleic acid decrease with seed maturity. The increase in oleic acid with seed maturity is normally accompanied by a decrease in palmitic and linoleic acid. Bovi (1982) Raheja et al. (1987) and Önemli (2012) reported that there was a negative correlation between oleic acid and linoleic acid. Holaday and Pearson (1974) found that higher temperatures during the last 4 weeks before harvest resulted in higher oil and oleic acid content and correspondingly higher O/L ratios. Oil content and fatty acid composition of peanut have been studied in different cultivars and different environments and it has been reported that the oil content of peanut cultivars varied between 37.9-56.3%, oleic acid (C18:1) 37.7-82.2%, linoleic acid (C18:2) 2.9-41.5%, palmitic acid (C16:0) 9.6-13.2%, stearic acid (C18:0) 1.6-3.7%, arachidic acid (C20:0) 1.2-1.7% and behenic acid (C22:0) 1.2-3.5% (Dwivedi et al. 1996; Yav et al. 2008; Önemli, 2012; Chaiyadee et al. 2013; Mzimbiri et al. 2014; Chowdhury et al. 2015; Gölükcü et al. 2016 and Gulluoglu et al. 2016b). Peanut has been grown as a main and double cropped after a small grain harvest in the Cukurova region in Turkey. Fatty acid composition of peanut is not constant. The fatty acid composition of peanut oil varies depending on varieties, growing conditions and maturity. The objective of the study is to investigate the effect of harvesting times on oil content and fatty acids composition of peanut varieties grown as main crop in Mediterranean region in Turkey.

Material and methods

This experiment was conducted in 2015 at Research Farm of Cukurova University (41°04´N, 36°71´E, and 36 m) as a main crop. Halisbey, Sultan, Arioglu-2003, Osmaniye-2005, NC-7, Batem-5025, Flower-22, Flower-32, Flower-36, Brantley and Wilson peanut varieties belonging to Virginia market type were used as a plant material in this research. The soil texture was clay loam. The soil tests indicated that pH of 7.5 with high concentrations of K_2O and low concentrations of P_2O_5. In addition, the organic matter and nitrogen content of the soil were very low. The lime content was 20.5% in the upper layers with increased levels in lower layers. Mediterranean climate prevails in this region. Winters are warm and rainy, whereas summers are dry and hot. The average monthly air temperature and precipitation during the research period (April-September) was varied between 16.9-30.1^{o}C and 71.9 mm and 205.4 mm, respectively. The average relative humidity was between 47.9% and 69.0%. The differences between the year and long term for the climatic data were not significant (Anonymous, 2015). The experiment was designed at split plot design (harvesting times as main plots and varieties as subplots) and replicated three times. The experimental site was cultivated deeply by the moldboard following the harvest of the previous crop in the autumn and then the soil was prepared by using disked-harrowed the day of planting. 250 kg ha^{-1} of Di-ammonium phosphate (45 kg ha^{-1} N, 115 kg ha^{-1} P_2O_5) fertilizer was applied and incorporated to soil before planting. Ammonium nitrate (33%N) at the rates of 200 kg ha^{-1} was applied two times; before first (beginning of flowering) and second (pod formation) irrigation. Plots consisted of 4 rows 5.0 m long and 70 cm apart. The seeds were sown in line manually by hand on 5 April 2015 and with 70 x 15 cm distance. During the growing period, recommended pesticides and fungicides were applied to control insects and diseases. During the growing period, other standard cultural practices were done. The plants were harvested by hand at four different times with one week intervals (149 DAS, 156 DAS, 163 DAS and 170 DAS) at the beginning of September.

Data collection and analysis

Determination of oil content: Seeds of each variety were harvested separately at maturity stage when the seed moisture was reduced to 12% or less at both growing seasons. Once harvested, seeds were cleaned and dried to approximately 7% moisture. Seed oil content in three samples from each genotype was determined by Soxhlet extractor according to AOCS (2010) using petroleum ether (40-60°C) as a solvent. Determination of fatty acids content: fatty acid profile was measured as *fatty acid methyl esters* using Gas Chromatograph (GC) according to AOCS (2010). O/L was calculated by the oleic acid content (%) to linoleic acid content (%) ratio (Gulluoglu et al. 2016b). The collected data on different parameters were statistically analyzed to obtain the level of significance using JUMP 8.1.0 package program with split plot design. The means differences were compared with the Least Significant Differences (LSD, 5%) Test.

Results and discussion

Fatty acids composition

The average data belonging to saturated and unsaturated fatty acids content, oil content and O/L values of peanut varieties at different harvesting times has been presented in Table 1 and 2. The major fatty acids components are oleic acid, linoleic acid and palmitic acid in peanut oil. Peanut oil is rich in oleic and linoleic acids. The amount of saturated and unsaturated fatty acids in peanut oil varies between 10.92% and 17.47% and between 81.13% and 94.81%, respectively.

Table 1. The saturated fatty acids content of peanut varieties at different harvesting times in main crop growing season

Treatments	Palmitic acid (%)	Stearic acid (%)	Arachidic acid (%)	Behenic acid (%)	Lignoceric acid (%)
Harvesting Times (A)					
149 DAS	10.16	3.23	1.22	2.80	1.64
156 DAS	9.81	3.34	1.19	2.76	1.59
163 DAS	9.46	3.50	1.21	2.83	1.57
170 DAS	9.15	3.73	1.21	2.86	1.55
Varieties (B)					
Halisbey	9.76	3.28	1.21	3.11	1.84
Sultan	10.01	3.47	1.17	2.94	1.64
Arioglu-2003	10.14	3.12	1.15	2.69	1.79
Osmaniye-2005	10.30	2.80	1.25	2.99	1.82
NC-7	8.77	3.32	1.18	2.82	1.42
Batem-5025	8.42	3.50	1.24	2.98	1.51
Flower-22	12.16	3.89	0.93	2.54	1.47
Flower-32	11.57	4.04	0.93	2.59	1.48
Flower-36	11.52	4.14	0.90	2.35	1.43
Brantley	5.55	3.28	1.54	2.95	1.62
Wilson	7.92	3.11	1.77	2.98	1.591.59
LSD (%5_A)	0.651	0.039	NS	0.019	NS
LSD (%5_B)	0.220	0.059	0.046	0.059	0.068
LSD (%5_{AxB})	0.441	0.119	NS	0.118	NS

As it can be seen from Table 1, the differences between the harvesting times were statistically significant for the palmitic acid, stearic acid and behenic acid percentage, but it was not significant for the arachidic acid and lignoceric acid percentage. The palmitic acid, stearic acid, behenic acid, arachidic acid and lignoceric acid percentages varied between 9.15-10.16%, 3.23-3.73%, 2.76-2.86%, 1.19-1.22% and 1.55-1.64%, respectively at the harvesting times (Table 1). The stearic acid percentage was increased when the harvesting date was delayed from 149 DAS to 170 DAS, but

palmitic and lignoceric acid content was decreased in peanut varieties. The average palmitic, stearic, arachidic, behenic and lignoceric acids percentage of peanut varieties varied between 5.55-11.57%, 2.80-4.14%, 0.90-1.77%, 2.35-3.11% and 1.42-1.84%, respectively. The differences between the peanut varieties for the saturated fatty acids were statistically significant. The interaction between the palmitic acid percentage x harvesting time, stearic acid percentage x harvesting time and behenic acid percentage x harvesting time were significant. The fatty acid composition of peanut oil varies depending on the genotype, seed maturity, climate conditions, growth location, and interaction between these factors (Carrin and Carelli, 2010). The fatty acids composition of Virginia type peanut varieties varies between 9.0-9.1% palmitic, 2.2-2.4% stearic, 56.4-60.3% oleic, 24.2-26.8% linoleic, 1.1-1.8% arachidic, 1.0-1.1% eicosenoic and 1.8-2.4% behenic acids (Brown et al. 1975). The palmitic acid percentage of the peanut varieties was found the highest among the saturated fatty acids. The saturated fatty acids content in peanut oil were strongly influenced by genotype (Isleib et al. 2008). Young et al. (1972) grew eight different peanut cultivars in Oklahoma for one year to assess effects of digging date on oil quality. They dug at five different digging dates, starting with 113 DAP for early maturing and 120 DAP for later maturing genotypes. Digging delays tended to give peanut oil with higher stearic and oleic acid and less linoleic acid. The results are corresponded well with the findings of Knauft et al. (1986), Dwivedi et al. (1996), Andersen and Gorbet (2002), Yav et al. (2008), Önemli (2012), Chaiyadee et al. (2013), Mzimbiri et al. (2014), Chowdhury et al. (2015), Gölükcü et al. (2016) and Gulluoglu et al. (2016a).

Table 2. The oil content, unsaturated fatty acids content and O/L value of peanut varieties at different harvesting times in main crop growing season

Treatments	Oil content (%)	Oleic acid (%)	Linoleic acid (%)	Linolenic acid (%)	O/L value*
Harvesting Times (A)					
149 DAS	47.8	52.83	24.44	1.77	2.162
156 DAS	48.6	53.97	23.42	1.78	2.304
163 DAS	49.4	55.08	22.65	1.79	2.432
170 DAS	50.3	56.05	21.94	1.78	2.555
Varieties (B)					
Halisbey	49.4	53.69	23.66	1.80	2.269
Sultan	49.2	53.71	24.62	1.80	2.182
Arioglu-2003	50.7	52.41	25.09	1.74	2.089
Osmaniye-2005	51.0	51.53	26.69	1.69	1.931
NC-7	47.3	59.77	17.79	1.75	3.360
Batem-5025	50.4	59.79	17.29	1.86	3.458
Flower-22	46.6	46.12	29.48	1.82	1.564
Flower-32	46.5	43.55	32.06	1.84	1.358
Flower-36	49.2	46.10	30.00	1.76	1.537
Brantley	47.8	79.21	2.19	1.77	36.169
Wilson	51.1	53.43	25.39	1.75	2.104
LSD (%5_A)	0.70	0.399	0.215	NS	-
LSD (%5_B)	1.17	0.341	0.381	0.022	-
LSD (%5_{AxB})	2.34	0.682	0.762	0.043	-

*O/L value: Oleic acid (%)/Linoleic acid (%)

Peanut oil is rich in oleic and linoleic acids. The oleic acid, linoleic acid and linolenic acid percentage varied between 52.05-56.05%, 21.94-24.44% and 1.77-1.79% respectively at the harvesting times (Table 2). The differences between the harvesting times were significant for the oleic and linoleic acids percentage. While the oleic acid percentage was 52.83% at the harvesting 149 DAS, it increased up to 56.05% at the harvesting 170 DAS. As the harvesting time was delayed, the oleic acid

percentage increased. However, the linoleic acid percentage was decreased from 24.44% to 21.94% when the harvesting time was delayed from 149 DAS to 170 DAS (Table 2). As the harvesting time was delayed, the linoleic acid percentage decreased substantially. Statistically significant differences were found among the peanut varieties for oleic and linoleic acids percentage. The average oleic acid percentage ranged from 43-55 to 79.21% (Table 2). The highest oleic acid percentage was recorded in Brantley (79.21%) and the lowest in Flower-32 (43.55%). Brantley was a high oleic type genotype and for this reason, its oleic acid percentage was found high. The linoleic acid percentage of peanut varieties varied between 2.19-32.06%. The highest linoleic acid percentage was found in Flower-32 (32.06%) and the lowest was in Brantley (2.19%). Andersen and Gorbet (2002) reported that oleic acid content in peanut genotypes varied from 21 to 85% and linoleic acid from 2 to 43%. Brown et al. (1975) reported that, oleic and linoleic acid accounted for 75-80% of the total fatty acids in peanut oil. Escobedo et al. (2015) reported that the peanut oil was rich in oleic and linoleic acids. Peanut oil composition is influenced by several groups of factors including environmental factors, genetic factors and interaction between environmental and genetic factors (Andersen and Gorbet, 2002; Isleib et al. 2008 and Chaiyadee et al. 2013). Andersen and Gorbet (2002) reported that seed maturity can also influence the fatty acid composition of peanut. In general, oleic acid increases and linoleic acid decrease with seed maturity. Young et al. (1972) found that digging delays tended to give peanut oil with higher stearic and oleic acid and less linoleic acid. Knauft et al. (1988) pointed out that digging delays tended to give peanut oil with higher stearic and oleic acid and less linoleic acid. Bovi (1982) Raheja et al. (1987) and Önemli (2012) reported that there was a negative correlation between oleic acid and linoleic acid. These results are in agreement with the findings of Young et al. (1972), Young and Worthington (1974), Bovi (1982), Raheja et al. (1987), Knauft et al. (1986), Hinds (1995), Dwivedi et al. (1996), Andersen and Gorbet (2002), Isleib et al. (2008), Önemli (2012), Chowdhury et al. (2015) and Gulluoglu et al. (2016a).

Oil content

As it can be seen from Table 2, the differences between the harvesting times were statistically significant for oil content. The oil content varied between 47.8-50.3%. The oil percentage was increased when the harvesting time was delayed. The oil content was 47.8% at first harvesting date (149 DAS) while it was increased to 50.3% at forth harvesting date (170 DAS). Court et al. (1984) utilized five successive digging dates in Ontario ranging from 113 DAP over two years to examine differences in two genotypes. They found that delayed digging, increased oil content. Singh and Oswalt (1995), Lu et al. (1997) and Canavar and Kaynak (2013) reported that oil content was increased by delaying the harvesting time. The oil content of peanut varieties varied between 46.5-51.1% on based of dry weight and the highest oil content (51.1%) was in Wilson and the lowest (46.5%) was in Flower-32 varieties. The differences between the peanut varieties were statistically significant. Holaday and Pearson (1974), Brown et al. (1975), Raheja et al. (1987), Hassan et al. (2005), Yav et al. (2008) and Isleib et al. (2008) reported that the oil percentage of peanut seed varies between 35 to 56% depending on genotype and growing conditions, and the oil content of peanut varieties influence by genotype, seed maturity, climatic conditions, geographical location and growing conditions. Similar result were reported by some other researchers (Özcan and Seven, 2003; Yav et al. 2008; Hassan and Ahmed, 2012; Önemli, 2012; Chowdhury et al. 2015 and Gölcüklü et al. 2016).

Oleic acid to Linoleic acid ratio (O/L)

Oleic acid to Linoleic acid ratio (O/L) and iodine value determines the quality, storability and shelf-life of peanut oil and its products. High-oleic peanut has longer self-life than low-oleic peanut and it has better flavor quality or stability than low-oleic peanut (Brown et al.1975; Yav et al. 2008 and Chaiyadee et al. 2013). The O/L ratio of peanut varieties varied between 2.162-2.555 at the harvesting times (Table 2). The O/L value was increased from 2.162 to 2.555 when the harvesting delayed to 170 DAS from 149 DAS. These results showed that early harvesting is not suitable for the oil quality and processing. The O/L value of the peanut varieties (excluded Brantley variety) varied in

between 1.358-3.458 (Table 2). The O/L ratio was higher in Batem-5025 and NC-7 and was lower in Flower-32, Flower-36 and Flower 22 varieties. Escobedo et al. (2015) reported that O/L value of peanut varieties varied in between 1.8-2.1 grown in Mexico. The O/L ratio was found very high in Brantley (36.169). The O/L is very high in oleic type peanut varieties due to high oleic acid percentage. Holaday and Pearson (1974) found that higher temperatures during the last 4 weeks before harvest resulted in higher oil and oleic acid content and correspondingly higher O/L ratios. The authors postulated that this temperature -O/L relationship may provide at least partial explanation for observed problems with oxidative stability in peanuts grown in colder climates or with colder temperatures during the later weeks of the growing season. These findings were supported by some other researchers (Young and Worthington, 1974; How and Young, 1983; Dwivedi et al.1996; Hashim et al. 1993; Andersen and Gorbet, 2002; Chaiyadee et al. 2013 and Gulluoglu et al. 2016a).

Conclusions

Oil content is an important quality characteristic in peanut seed and the oil content influences by genotypic variation, growing conditions and maturity. The oil content increases by delaying the harvesting times. The nutritional and storage qualities of peanut are determined by its fatty acids composition. The fatty acid composition of peanut seed oil influenced by genotypic variation, air and soil temperature, planting date, soil nutrient, growing conditions and maturity. The seed maturity can also influence the fatty acid composition of peanut. In general, oleic acid increases and linoleic acid decrease with seed maturity. The increase in oleic acid with seed maturity is normally accompanied by a decrease in palmitic and linoleic acid. There was a negative correlation between oleic acid and linoleic acid. Higher temperatures before harvest resulted in higher oil and oleic acid content and correspondingly higher O/L ratios. As a result; the oil content, oleic acid and stearic acid percentages of the peanut varieties was increased when the harvesting times delayed. The oil and fatty acids content of peanut varieties were found differ at the harvesting times.

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