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Effect Of The Storage Period On The Physico-Mechanical And Some Quality Properties Of Sunflower Seeds *(Helianthus annuus L.)* *

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Abstract: In this study, effect of the storage periods (15, 30, 45, 60, 75, 90, 105, 120, 135, 150 days) on the physico-mechanical and some quality properties of the sunflower ***(****Helianthus annuus L.)*, seeds (*Sanbro* hybrid variety), one of the most important raw materials in the vegetable oil industry, have been analyzed. As a result of the study, the correlation between the bulk density and the storage period was found to be significant with probability P<0.01. In contrast, the correlation between the true density and the storage period and between the angle of internal friction and the storage period was not found to be significant. In connection with the storage period, changes in the static coefficient of friction between the grain and the friction surface was not found to be significant in concrete and galvanized steel surfaces, while in wood surfaces was found to be significant with probability P<0.01. It has been calculated that there is an important statistical correlation between the oil content (OC) and the storage period, and between the free fatty acid content (FFA) and the storage period in the sunflower seeds with probability P<0.01, respectively.
Keywords: Sunflower, storage period, physico-mechanical properties, oil content, acidity

Depolama Süresinin Ayçiçeğinin *(Helianthus annuus L.)* Fiziko-Mekaniksel ve Bazı Kalite Özellikleri Üzerine Olan Etkileri

Özet: Bu çalışmada bitkisel yağ sanayinin en önemli hammaddelerinden birisi olan ayçiçeğinin *(Helianthus annuusL.)* Sanbro çeşidi tohumlarında, depolama süresinin (15, 30, 45, 60, 75, 90, 105, 120, 135, 150 gün) tane fiziko-mekanik ve bazı kalite özellikleri üzerine olan etkileri araştırılmıştır. Araştırma sonucunda, birim hacim ağırlık-depolama süresi arasındaki ilişki P<0.01 olasılık düzeyinde önemli bulunurken, özgül ağırlık-depolama süresi ve içsel sürtünme açısı – depolama süresi arasındaki ilişki önemli bulunmamıştır. Depolama süresine bağlı olarak ürün-sürtünme yüzeyleri arası statik sürtünme katsayılarındaki değişim beton ve galvanize çelik yüzeylerde önemsiz, ahşap yüzeyde ise P<0.01 olasılık düzeyinde önemli bulunmuştur. İstatistiksel açıdan ayçiçeği numunelerinde depolama süresi - yağ oranı ve depolama süresi - asitlik oranı arasında P<0.01 olasılık düzeyinde önemli bir ilişkinin olduğu saptanmıştır.
Anahtar Kelimeler: Ayçiçeği, depolama süresi, fiziko-mekanik özellikler, yağ oranı, asitlik

Nomenclature

ρ_b	bulk density, kg.m^{-3}	N	load applied on the sample, kg
G_1	free weight of bulk density bucket, kg	A	cellular area, cm^2
G_2	weight of bulk density bucket with sunflower, kg	τ	shear stress, pressure on cutting edge, kpa
V_b	volume of bulk density bucket, m^3	T_s	shear force, load on cutting edge, kg
ρ_t	true density, kg.m^{-3}	c	coefficient of cohesion
m_s	weight of liquid, kg	μ_s	static coefficient of friction
m_w	weight of air dry sample, kg	F_s	force starting movement at surface interface, kg.m^{-2}
V_s	volume of liquid, m^3	W_s	force applied to surface interface, kg.m^{-2}
$V_ç$	volume of NAOH used in solution, (ml)	OC	oil content, (%)
V_w	volume of sample, m^3	FFA	free fatty acids values, (%)
φ	angle of internal friction, degrees	m_{oil}	mass of the extracted oil, (g)
σ	normal stress, kPa	m_s	mass of sample, (g)

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1. Introduction

In the last years, the world production of sunflower seeds (*Heliantus annuus* L.) has had a significant increase compared to other seed oil cultivation. Sunflower seeds are very rich in oil (about 50 % wt.) and from a chemical point of view the oil is considered very good for human consumption, because of its high ratio polyunsaturated/saturated fatty acids and the high content in linoleic acid. In addition, sunflower seeds represent an important source of vegetable oil and its protein fraction characterized by relatively well-balanced amino acid pattern, is recognized as a potential source

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of proteins for human consumption (Salgın et al., 2006). The world's major sunflower seed producing countries are Russia, Ukraine, Argentina and some of the European Union Countries (FAOSTAT, 2010). Sunflower seed is the most important raw material for the vegetable oil industry in Turkey is sunflower. Turkey's ecological conditions are upmost favorable for the cultivation of sunflower (Onurlubaş and Kızılaslan, 2007). In the year 2009, the world's sunflower seed production is 35.642.649 tonnes, also Turkey's sunflower seed production is 992.000 tonnes; FAOSTAT, 2010).

In the designing of warehouses, three basic factors should be taken into consideration. These factors; the physico–mechanical properties of stored grain, geometry of warehouse, the interaction between grain and warehouse wall (Ayuga et al., 2005).The theoretical basis of grain mechanical has been formulated for mineral materials. However, granular materials with biological origin (wheat, barley, soybean, corn, sunflower, etc.) in comparison mineral-based materials (clay, gravel, sand, crushed stone, etc.) on the particles structure of bio-based materials and mechanical properties, grain moisture content is largely effective. Therefore, in the designing of warehouses and silos should be taken into consideration moisture to content of grain (Molenda et al., 2004).The basic physico-mechanical properties of agricultural products are bulk and true density, angle of internal friction, static coefficient of friction (Molenda and Horabik, 2005).

The content of free fatty acids (FFA) in vegetable oils represents an important quality factor in oil crops.Unsuitable storage conditions such as high temperature and humidity are effective on the increase of FFA content in oil crops. For industrial storage, it is important to have a low temperature, low levels of humidity and, in particular, to reduce risks of damage to the sunflower seeds (Christian and Bettina, 2006).

Jones and Shelton (1994) reported that if increasing of moisture content of granular agro-materials during the storage period, breakage and damage of its by mechanical effects also increase. Particularly, if the moisture content reach to 18-20% levels, it can be the breakages and damages at the highest level. In this case, the broken and damaged granules in comparison with strong granules are 3-4 times faster deterioration.

In Turkey, the annual value of quality losses depend on unsuitable storage conditions in the storage of sunflower seeds is approximately 10 million U.S. $ (Gaytancıoğlu, 1999). This study was performed to examine the effect of the storage period on physico-mechanical and quality properties of sunflower seeds (*Heliantus annuus* L.).

2. Materials and Methods

2.1. Raw Materials and Experimental Design

The experiments were carried out with seeds of *the Sanbro* hybrid variety widespread cultivated in the Black Sea Region of Turkey in 2008-2009 storage periods. This variety is grown as oil variety in the region. Linoleic and oleic acid content is higher, seed pods are thin, skin color is black. The sunflower seeds used in the laboratory experiments during the storage period (15,30,45,60,75,90,105,120,135,150 days) were taken by using the drilling system from the middle of warehouse which is belonging to the Black Sea Cooperatives Union of Oilseeds (Fig. 1).

Firstly, sunflower seeds brought to laboratory during the storage period were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature, broken seeds. The initial moisture content of sunflower seeds was determined by oven drying at 105±5 ^{o}C for 4 h (AOCS,1998;Yağcıoğlu**,**1999).The sunflower seeds obtained was placed in desiccators and stored at room temperature (23±2 ^{o}C) before use.

2.2. Determination of Physical Properties

The moisture content of samples ($M_{d.b}$) was calculated as follows (Bakker, 1999) :

$$M_{d.b} = \left(\frac{M_{w.b}}{100 - M_{w.b}} \right) x100 \qquad [1]$$

To determine the bulk density of the experimental samples the method defined by

Fig. 1. Taking samples from the warehouse

Mohsenin (1980), and Singh and Goswami (1996) was used. The weight of a bulk density container of 1000 ml volume and 108 mm height was used to determine bulk density. The bulk density container was filled up to 5 cm above the top. The sunflower seeds were then allowed to settle into the container and the bulk density was calculated from the following equation (2):

$$\rho_b = \frac{G_2 - G_1}{V_b} \qquad [2]$$

The liquid displacement method as described by Kibar and Öztürk (2009) was used to determine the true density of sunflower seeds. In this method, toluene (C_7H_8) was used in place of water because it is absorbed to a lesser extent by sunflower seeds and its surface tension is low. To calculate true density, the air dried weight for samples was firstly determined. The samples were then submerged in toluene and the displacement volume was determined. In the second stage, the true density of samples was calculated by using Equation (3) as follows:

$$\rho_t = \frac{m_s + m_w}{V_s + V_w} \qquad [3]$$

2.3. Determination of Mechanical Properties

To determine the angle of internal friction of sunflower seeds the direct shear method was used according to Zou and Brusewitz (2001), Moya et al. (2002), Kibar and Öztürk (2009). The velocity used during the experiment was 0.7 mm.min^{-1} and the angle of internal friction of seeds was calculated by using Equations (4,5,6).

$$\sigma = \frac{N}{A} x100 \qquad [4]$$

$$\tau = \frac{T_s}{A} x100 \qquad [5]$$

$$\tau = (c + \sigma \, x \tan \varphi) \qquad [6]$$

The static coefficients of friction of the samples were determined according to the method given by Beyhan et al. (1994). Wood, concrete (C30) and galvanized steel surfaces were used as friction surfaces. During the experiment, the test surface moved at a low velocity (2.4 cm.sec^{-1}). The surfaces were driven by a 12 V, adjustable direct current motor and strength of friction was measured by using a digital dynamometer. The static coefficient of friction was calculated from the constant strength of friction read in the digital dynamometer after movement occurred at the interface. The static coefficients of friction of sunflower seeds were calculated by using Equation (7).

$$\mu_s = \frac{F_s}{W_s} \qquad [7]$$

2.4. Quality Analysis

To determine the oil content (OC) and the free fatty acids values (FFA) of sunflower seeds was used the Soxhlet extraction method. In this context, the oil content (OC) and the free fatty acids values (FFA) was determined by using Equations (8, 9) (AOCS 1998 ; Nas et al., 2001).

$$OC = \left(\frac{m_{oil}}{m_s} \right) \times 100 \qquad [8]$$

$$FFA(Oleic\ acid\ \%) = \left(\frac{V_{ç}}{m_{oil}} \right) \times 2{,}8 \qquad [9]$$

2.5. Data Analysis

Experiments were performed in three replications. The results obtained were subjected to analysis of variance using SPSS 10.0 software (Yurtsever, 1984).

3. Results and Discussion

The values of moisture content ($M_{d.b}$) of test samples used in research during the storage period are given in Table 1.As can seen from the Table 1, the moisture content of sunflower seeds during the storage period increased. These data are parallel with the values (% 4 - 20) given in Gupta et al. (1997).

The grains bulk density at storage period varied from 407 to 436 kg.m^{-3} (Fig. 2). As can be seen from Fig.2, values of bulk density demonstrated fluctuate depending on the storage period. The main reason for this is controlled environmental conditions is not be in the warehouse provided the test samples. As a result of analysis of variance, a significant relationship at the 1% level probability was observed between storage period and bulk density.

In the studies conducted on biological materials under laboratory conditions were determined a positive or a negative relationship depending on the crop between bulk density and moisture content. For example; Jain and Bal (1997), Sahoo and Srivasta (2002), Paksoy and Aydın (2004), Yalçın and Özarslan (2004) , Baryeh and Mangope (2005) has reported a positive relationship for millet, okra seed, edible squash, vetch seed and pigeon pea between bulk density and moisture content respectively.

Whereas, Baryeh (2001), Aydın et al. (2002), Çalışır et al. (2005), Dursun and Dursun (2005), Coşkun et al.(2006), Karababa (2006) and Yalçın(2006) has reported a negative relationship for bambara groundnuts, Turkish mahaleb, rapeseed, caper seeds, popcorn kernels, cowpea seed between bulk density and moisture content respectively.

Table 1. Moisture contents ($M_{d.b}$) of test samples

Storage period (day)	Moisture content ($M_{d.b}$) (%)
01-15	5,69
15-30	5,93
30-45	6,50
45-60	6,69
60-75	7,20
75-90	9,20
90-105	10,01
105-120	10,50
120-135	11,80
135-150	12,30

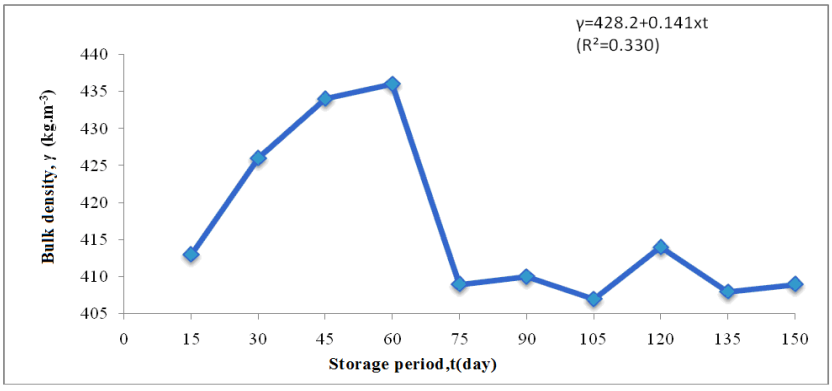

Fig. 2. The effect of storage period on bulk density

The grains true density at storage period varied from 745 to 827 kg.m^{-3} (Fig.3).As can be seen from Fig.3, the values of true density demonstrated fluctuates depending on the storage period. As a result of analysis of variance, a significant relationship wasn't observed between storage period and bulk density.

Gupta and Das (1997), Ogunjimi et al.,(2001), Baryeh (2002), Paksoy and Aydın (2004), Yalçın and Özarslan (2004), Coşkun et al. (2006), Altuntaş and Yıldız (2007) have reported a positive relationship for sunflower seeds, locust bean, millet, edible squash vetch seed, sweet corn, faba bean between true density and moisture content under laboratory conditions respectively.

Whereas, Altuntaş et al. (2005), Aydın et al. (2002), Dursun and Dursun (2005), Karababa (2006), Özarslan (2002), Saçılık et al. (2003) ve Zewdu and Solomon (2008) have reported a negative relationship for fenugreek seeds, Turkish mahaleb, caper seeds, popcorn kernels, cotton seeds, hemp seed, grass pea between true density and moisture content under laboratory conditions respectively

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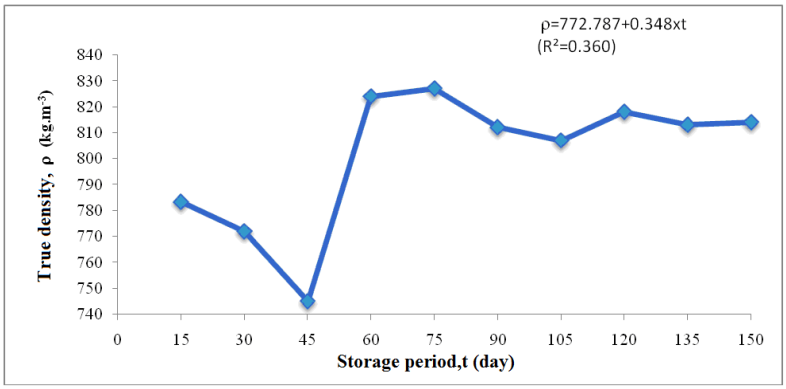

Fig.3.The effect of storage period on true density

The angles of internal friction of test samples are presented in Fig. 4. As can be seen from Fig.4, the angles of internal friction of test samples at the storage period didn't show a significant change. Therefore, the relationship between storage period and the angle of internal friction hasn't been determined significantly.

The static coefficients of friction determined with respect to galvanized steel, wood and concrete (C30) surfaces for test samples are presented in Fig.5. When the static coefficient of friction results were evaluated statistically, variance in the static coefficient of friction depending on storage period wasn't

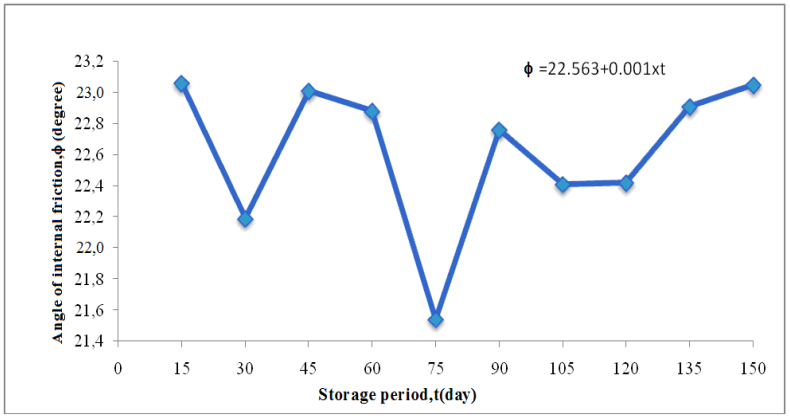

Fig.4. The effect of storage period on angle of internal friction

Significant for concrete and galvanized steel surfaces but for wood surface was significant at the 1% level probability. The sunflower seeds purchased from the union member farmers are stored until the seeds are processed to oil (approx. 7 month). In this context, it is important the seasonal variation of static coefficients of friction. The highest values for all test surfaces were observed in representing samples between 60-90 days. Some researchers have reported that as the moisture content of grain increased, the static coefficients of friction increased (Altuntaş et al., 2005; Altuntaş and Mutlu, 2007; Altuntaş and Yıldız, 2007; Baryeh, 2001; Baryeh, 2002;Çalışır et al. 2005b; Coşkuner and Karababa, 2007a; Coşkuner and Karababa, 2007b).

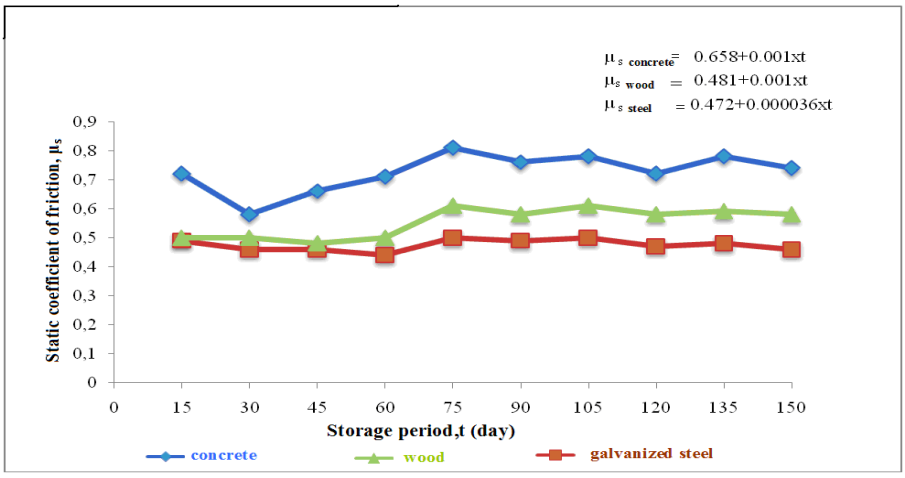

Fig.5. The effect of storage period on static coefficient of friction

The values of oil content (OC) of sunflower seeds during the storage period are presented Fig.6. It was observed that the oil content of seeds decreased linearly during the storage period. If the results of the oil content were evaluated statistically, variance in the oil content of seeds depending on the storage period was significant at the 1% level probability.

Simic et al. (2007) reported that, the changes in seed oil content in maize, soybean, and sunflower were affected by storage longevity under two levels of storage conditions differed in terms of air temperature and relative air humidity: 25°C and 75% and 12°C and 60%, respectively. The obtained results of the study showed that storage longevity was negatively associated with oil content. At storage conditions at 12°C and 60%, decreasing of seed oil content was less by 0.55% (maize), 1.30% (soybean) and 1.75% (sunflower) than in storage conditions at 25°C and 75%. Affected by storage longevity, in average, seed oil content decreased by 0.82% in maize, 2.19% in soybean and 8.53% in sunflower.

The free fatty acids (FFA) of sunflower oil makes it very important oil to be used for cooking. If the oil is refined and consumed, it will supply the essential fatty acid needed in the body. This will reduce the risk of cardiovascular diseases in human being. Changing the free fatty acids values (FFA) during the storage period are presented Fig.7. As can be seen from Fig.7, the free fatty acids values (FFA) in the sunflower seeds during storage period have increased over 400%. According to the results of analysis of variance, the relationship between the free fatty acids values (FFA) and the storage period was found significant at the 1% level probability. Gaytancıoğlu (1999) reported that the increases in the free fatty acids values (FFA) of sunflower seeds during the storage period, the crude oil refining process are causing significant economic losses. Notedly, if the free fatty acids values (FFA) of oilseeds reaches the

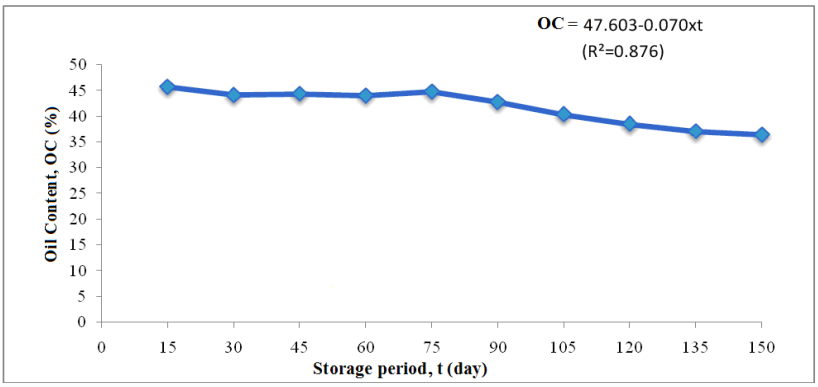

Fig.6.The effect of storage period on the oil content (OC)

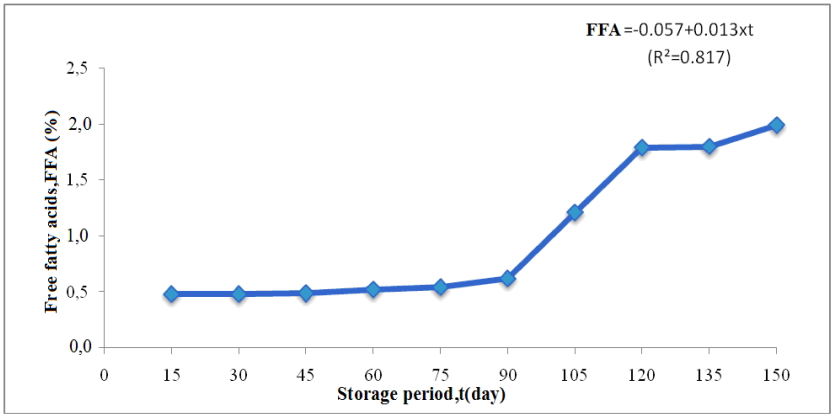

Fig.7.The effect of storage period on free fatty acids

levels of 1.5%, in the crude oil refining may occurs losses up to 2.0 %. Christian and Bettina (2006) also reported that, the content of FFA in oil represents an important quality parameter in oil crops. With regard to the processing of oilseeds, the threshold value is set to a maximum of 2% FFA in the crude oil of sunflower seeds. This is because the FFA have to be removed during refining, which leads to a reduced oil yield and, consequently, to a reduction in price.

In this research was determined the free fatty acids values (FFA) of sunflower seeds at the end of storage period reached up to 1.99 %. Therefore, in the crude oil refining are likely to occur a significant economic loss

4. Conclusion

The study of effect of the storage period on physico-mechanical and some quality properties of sunflower seeds *(Helianthus annuus L.)* revealed the following results:

1. At the end of 150 day's storage period, the moisture content of sunflower seeds increased from 5.93 % to 12.3 %.

2. A significant relationship at the 1% level probability was observed between storage period and bulk density. However, as statistically a significant relationship was not determined between storage period and true density with angles of internal friction

3. Changing in the static coefficients of friction depending on storage period for some surfaces was significant at the 1% level probability.

4.The oil content (OC) of sunflower seeds have decreased linearly during the storage period. The changes in the oil content of seeds depending on the storage period were significant at the 1% level probability.

5. The free fatty acids values (FFA) of the sunflower seeds depending on the storage period have increased over 400%. The relationship between the free fatty acids values (FFA) and the storage period was found

significant at the 1% level probability. If human health is taken into consideration, refining of crude oil will be more expensive. The increase in the free fatty acids values (FFA) of seeds is likely to occur a significant economic loss in the refining process of crude oil.

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