The Effects of Dehulling on Physicochemical Properties of Seed Oil and Cake Quality of Sunflower

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Abstract

This paper reports on oil yield, physicochemical properties of oil and cake quality obtained by expeller extraction of dehulled and undehulled seeds from two varieties of sunflower originated from Tanzania. The results showed significant differences in oil yield between undehulled and dehulled seeds also among the varieties. Oil yield from dehulled seeds was significantly higher (31−35.1%) than the yield from undehulled seeds (~19.7%). When compared physicochemical parameters (refractory index, saponification value, iodine value, free fatty acid value and peroxide value) of oils with standard values as recommended by Tanzania Bureau of Standard, the oil extracted from dehulled seeds were found to be within the range of values specified but the oil from undehulled was of poor quality at many instances. However, the physicochemical properties of oils from the two varieties did not differ significantly in most of the properties except for peroxide value. The cake composition from dehulled seeds was characterised by high crude protein (~44%) and low crude fibre contents (~17%), indicating improved quality. The results suggest that high yield and desired properties of both oil and cake can be achieved when seeds are dehulled, therefore, this process should be incorporated by Tanzanian sunflower processors.

Key words: Sunflower cultivar, seed oil, oil yield, dehulling, animal feed.

Introduction

Sunflower (*Helianthus annuus* L.) is an important cash crop for production of edible oil in Tanzania. The annual production of sunflower seeds ranges between 75,000 to 100,000 tons from 2001 to 2005 with Singida and Rukwa region being the leading producers. The production has been dramatically increasing to more than threefold (about 350,000 tons) since 2006 due to partnership between the government and the international donors (Zheng, 2011). From these seeds (350,000 tons) potentially 140,000 tons of oil can be extracted. Other sources of edible oil include groundnuts, sesame, cotton seeds and palm oil.

Oil is extracted from sunflower seeds by using either mechanical expression or solvent extraction, or both methods (Dufaure *et al.,* 1999; Kartika *et al.,* 2006). The solid residue left after oil extraction known as oil cake is used for making animal feed. Mechanical expression by continuous screw expeller is the most common method used for oil extraction (Amalia Kartika *et al.,* 2006; Pradhan *et al.,* 2011). This method is usually followed by solvent extraction to extract the remaining oil in the pressed cake (Singh and Bargale, 2000). However, Tanzania's entrepreneurs (mainly small and medium oil enterprises) do not use solvent to extract the remaining oil in the pressed cake (Kibazohi, 2004). Thus, up to 14 % of the available oil is left un-extracted leading to low oil yield (Bamgboye and Adejumo, 2007).

Furthermore, oil produced from undehulled seeds using screw expeller is of relatively poor quality due to the presence of undesirable characteristics including bad odour, dark yellowish colour and high wax content, which can significantly reduce the shelf life of the oil (Dorrell and Brady, 1997). Similarly, the use of cake produced by screw expeller in making livestock feeds has been limited due the high crude fibre content (Harmsen *et al.,* 2009). Undehulled seeds can also impair extraction efficiency and life span of the expeller due high crude fibre which is responsible for increasing wear and tear in the machine (Bamgboye and Adejumo, 2007).

Dehulling of seeds represents an innovative strategy for removing undesired characteristics of oil and for improving cake quality. In this process, the hull or seed coat is removed from the seed by using dehuller to obtain hull free kernels (Booth, 2004). For sunflower seeds, the process increases oil extraction efficiency, throughput capacity and also reduces wear and tear of the extraction equipment (Isobe et al., 1992). Studies show that up to 93.6 % of the oil can be recovered during mechanical expression of dehulled sunflower seed compared to 86 % from undehulled seed (Kartika *et al.,* 2006). This process also reduces the crude fibre content of the cake up to 13%, thereby increasing its nutrient value and marketability as livestock feed (Swick, 1999). However, this process has not been tested for sunflower seeds originating from Tanzania. Therefore, the objective of this study was to investigate the effect of dehulling on oil yield and physicochemical properties such as refractory index, saponification value, iodine value, free fatty acid value and peroxide value of the crude oil produced from dehulled sunflower seeds in comparison with the oil extracted from undehulled seeds. The chemical composition of oil cake produced from dehulled and undehulled seeds were also compared.

Materials and methods

Sunflower Seeds

Two sunflower seed varieties (Record and Kenya Fedha) used in this study were obtained from Ilonga Agricultural Research Institute (Kilosa, Tanzania). Before performing any test, the samples were manually cleaned to remove foreign materials, broken seeds and chaff and then were homogenised. The cleaned samples were then divided into two portions by quarter sampling technique. The first portion was dehulled using centrifugal dehuller (locally manufactured at the Department of Agricultural Engineering, Sokoine University of Agriculture). The second portion was not dehulled. All samples were stored in air tight container and stored at room temperature until the time of processing.

Oil Extraction

The sunflower seed samples were pressed using a continuous screw expeller (model ZX18, Habei nanpi machinery manufacture, Mumbai, India) available at Vyahumu Trust oil mill (Kihonda, Morogoro-Tanzania). Thirty five kilograms of dehulled or undehulled seeds from each variety were fed into the machine and pressed to extract the crude oil. After the extraction the oil was kept in dark containers (wrapped with aluminium foil) and stored at 4°C to allow sedimentation of foreign material to take place. After 72 hours, the oil was carefully decanted and filtered to remove any remaining fine particles. The obtained oil was weighed and the oil yield was determined by using Eq. 1.

$$O_y = \frac{W_o}{W_s} \times 100\% \qquad (1)$$

Where;

W_O is the weight of extracted oil (kg), W_S is the weight of seed sample

Physical and Chemical Characterization of Oil

Oil density was determined according to the procedures in American Society for Testing and Materials (ASTM) method D1298 (Noureddini *et al.,* 1992). Oil colour measurement was carried out using the Lovibond colour system in 2.54 cm cell, based on the expression (5R + Y) where R is the red pigment and Y is the yellow pigment. The oil odour (smell) was determined using a sensory analysis panel of five people (Ixtaina *et al.,* 2011). Oil odour was rated according the overall smell intensity using numerical scale of 1 to 4 with 1 = no odour, 2 = weak odour, 3 = moderate odour, 4 = strong odour. The refractive index of the oils was measured at 40 °C using Abbey refractometer (Prince, Melka Ganj Delhi).

The chemical properties (saponification value, peroxide value, iodine value and acid value) were determined using the standard methods (Othman and Ngassapa, 2012).

Determination of Cake Yield

The solid residue recovered after oil extraction (cake) was collected and weighed. The cake recovery (Cy) was calculated according to Eq. 2.

$$C_y = \frac{W_c}{W_s} \times 100\% \quad (2)$$

Where;

W_C is the weight of cake recovered (kg) and W_S is the weight of sample (kg).

Composition of the Cake

Crude Protein was determined according to Kjeldah method using block digestion and steam distillation (Helrich, 1990). The crude protein (CP) was calculated by using Eq. 3.

$$CP(\%) = \frac{14.01 \times C_B \times (T_t - B_v}{S_w \times 10} \times F \quad (3)$$

Where;

T_t is the titre (ml), B_v is the blank value, C_B is the concentration of HCl (0.1014 N/mol), S_w is the sample weight (g), and F is the factor for sunflower cake (6.25).

Crude fibre (CF) was analysed using Ankom technology (A2000, Ankom Technology Corp., New York) based on filter bag technique (ANKOM Technology, 2006) Approved by American Oil Chemistry' Society. The crude fibre was estimated using Eq. 4.

$$CF(\%) = \frac{(W_3 - (W_1 \times C_1))}{W_2} \times 100 \quad (4)$$

Where;

W_1-bag tare weight (g), W_2-sample weight (g), W3-weight of organic matter (loss of weight on ignition of bag and fibre) (g), and C_1-ash corrected blank bag factor (running average of loss on ignition of blank bag) (g).

Ether extracts were analysed using Soxtec apparatus (Soxtec 2000, Eden Prairie, Minnesota). Ether extracts were calculated using Eq. (5).

$$EE(\%) = \frac{C - B}{A} \times 100 \quad (5)$$

Where:

C, B, and A, represent weight of cup and residue ether extract (g), weight of cup (g), and weight of sample (g), respectively.

Statistical analysis

All experiments were performed in three replications. The results are presented as average and standard deviation (Average ± SD). One-way-analysis of variance (ANOVA) was performed to determine whether there were significant differences samples. The hypothesis was accepted or rejected at 95% confidence interval.

Results and discussion

Oil yield and physicochemical characterization

The removal of hull significantly increased the oil yield (35.2%) of dehulled seeds compared to the yield of 19.7% obtained from undehulled seeds (Figure 1). This increase was due to relative increase in proportion of the seed kernels which is in rich in oil as a result of removal of the hulls (Oomah and Mazza, 1997). The increase in oil yield may also be ascribed to the reduction in oil loss due to low absorption of oil by remained hull on the dehulled seeds ((Isobe *et al.,* 1992). The increase of oil yield due to dehulling is in agreement with the results reported in literature (Rahman *et al.,* 2001). To elucidate the variation of oil yield according to varieties, two varieties of sunflower were compared. The results showed significant differences (P> 0.05) in oil yield among the varieties (Figure 1). The highest yield for *Record* variety was 35.1% and that of *Kenya Fedha* was 31%. Generally, *Record* variety showed higher oil yield than *Kenya Fedha* in both cases when the seeds were dehulled or undehulled, suggesting that variety type has the impact on oil yield. Therefore, a combination of optimal selection variety and dehulling process will significantly increase oil yield.

The physical characteristics (odour, colour, relative density and refractive index) of oils from

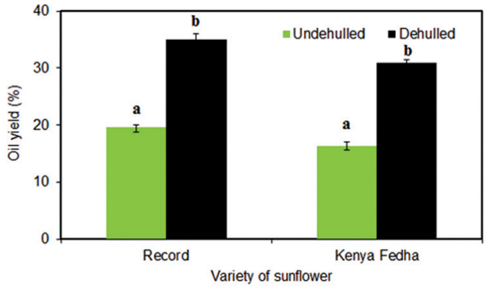

Figure 1: The percentage of oil yield from dehulled and undehulled sunflower seeds. The inserted letters with the similar alphabet means values significant difference at p<0.05.

dehulled and undehulled seeds are summarized in Table 1. The oil obtained from dehulled seeds had a weak odour (rated 2) compared to strong odour (rated 4) for oil obtained from undehulled seed. The weak odour might have been attributed to low wax content in oil from dehulled seeds due to the removal of the hull which is characterised by high waxes content (Carelli *et al.,* 2002). The oil from dehulled seeds had also bright yellowish colour and that from undehulled seeds had dark yellowish colour, suggesting that the colouring compounds were significantly removed from the seeds by dehulling (Abou-Gharbia *et al.,* 1997). The refractive index values obtained from dehulled and undehulled seeds were comparable (P>0.05). The values obtained from this study was also within the values recommended by TBS (2011) for sunflower oil (1.46−1.48) and was also in close agreement with the values reported for other edible oils such as soybean (1.466−1.470) and palm kernel (1.449−1.451) (Deli *et al.,* 2011). High refractive preliminary confirms the availability of differences in fatty acid between oils from different plants (Lazos, 1986). The oil from dehulled seeds had somewhat lower relative density (0.918−0.919) than that from undehulled seeds (0.921−0.923), but all values were within the values recommended by TBS (0.918-0.923) (Table 1).

Table 1 also reports the chemical characteristics of oils. The iodine value is a measure of the degree of unsaturated fatty acid, therefore it can be used to determine the amount double bonds present in oil which reflects the susceptibility of oil to oxidation. The results show that the oil from undehulled seeds had higher iodine values (148.9−153.7) than the values obtained from dehulled seeds (141). The low iodine value for oils from dehulled seeds suggests that they had low unsaturated fatty acid (Oomah and Mazza, 1997). Hence, they will have greater stability to oxidation than the oil from undehulled seeds. The decrease in total unsaturation and increase in free fatty acid due oxidation upon storage of oils has been reported elsewhere (Othman and Ngassapa, 2012).

Peroxide values is an index of rancidity,

Table 1: Physico-chemical composition of oil from dehulled and undehulled seeds for Record and Kenya Fedha varieties

Characteristics	Record variety		Kenya Fedha variety		TBS*
	Dehulled	Undehulled	Dehulled	Undehulled	
Odour	2	4	2	4	-
Colour	19	18	19	18	≤ 20
Relative density 20°C	0.918	0.921	0.919	0.923	0.918-0.923
Refractive index at 40°C	1.47±0.02	1.46±0.01	1.47±0.03	1.46±0.04	1.46-1.48
Saponification values (mg KOH/g oil)	179.6±0.7b	186.4±0.2a	176.9±0.8b	185.9±0.5a	188-194
Iodine values (g/g)	141.1±0.1c	148.9±0.3b	141.5±0.8c	153.7±0.3c	110-143
Peroxide value (Meq/kg oil)	1.05±0.02c	1.38±0.03b	1.84±0.04a	1.98±0.02a	≤ 10
Acid value	2.78±0.06c	3.68±0.01b	1.92±0.03d	4.67±0.04a	≤ 3

*Physico-chemical properties for sunflower seed oil recommended by TBS (2011).
[abcd] Means values in the same row differed significantly at p<0.05.

therefore low peroxide value indicates resistance of the oil to peroxidation during storage (Oluba, 2008). The peroxide value for all oils is low (1.05−1.98) compared to the maximum value acceptable for sunflower oils of 10 set by TBS (2011). Therefore the oil is stable and would not easily go rancid.

Saponification values provide a measure of average length of fatty acid chain that make up fat (Othman and Ngassapa, 2012). Oils from dehulled and undehulled seeds had saponification values below the range of values recommended by TBS (2011). However, oils from undehulled seeds had higher values (185.4−185.9) than that from dehulled seeds (176.9−179.6). The high values of saponification values observed in oils from undehulled seeds could be attributed to presence free fatty acid due contributed by the hulls which are rich in unsaturated fatty acids (Canibe *et al.,* 1999).

The acid value is among of the main characteristics that are necessary for the confirmation of edibility of oil. The acid value of 0.00 to 3.00 mg KOH/ g oil is recommended for application in cooking (Oderinde *et al.,* 2009). The oil from dehulled seeds could be suitable for cooking results while that from undehulled seeds will need more refineries (Table 1). The high acid value observed in oil from undehulled seeds could be ascribed to presence of the higher percentage of triglycerides, which can release free fatty acids during the extraction process and hence increase oil acidity (Wolff *et al.,* 1996).

Cake recovery and composition

Figure 2 depicts cake recovery after oil extraction from dehulled and undehulled seeds for the two varieties of sunflower. The cake recovery from undehulled seeds for *Kenya Fedha* variety had the highest recovery (65.1%) than that the observed from dehulled sees for *Record* variety (55.1%). Generally, lower cake recoveries were found for Record variety (55.1−59.4%) compared to that which was obtained from *Kenya Fedha* variety (62.3−65.1%). This could be due to high oil yield observed in *Record* variety (Figure 1).

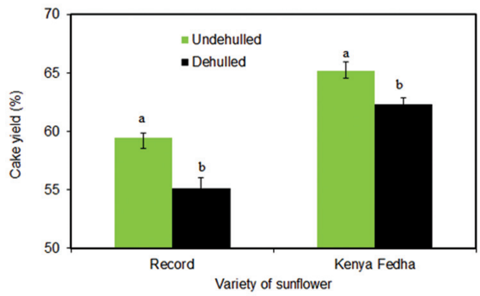

Figure 2: The percentage of cake yield from dehulled and undehulled sunflower seeds. The inserted letters with the similar alphabet means values significant difference at p<0.05.

Sunflower seed contains seed kernel and a seed coat or hull. However, the percentage of hull in a seed varies from 22 to 28 % depending on varieties, seed size and oil content (Gunstone, 2004). The hull fraction contains low levels of protein and high content of crude fibre. In this study, the removal of hull fraction considerably increased protein content (~44.9%) of the dehulled seeds (Table 2). The fibre content was reduced from 33.4% to 17.7% for *Record* and from 23.9 to 17.4% for *Kenya Fedha* varieties upon dehulling. These results

Table 2: Nutrient composition, ash and dry matter content of pressed cake from dehulled and undehulled seeds from two varieties of sunflower

	Record		*Kenya Fedha*		FAO (2012)
	Dehulled	Undehulled	Dehulled	Undehulled	
Dry matter (%)	96.8±0.6	97.2±0.3	97.0±0.3	97.5±0.4	91
Ash (%)	5.5±0.1b	7.1±0.1a	5.5±0.2b	6.9±0.6a	6.6
Crude protein (%)	44.5±0.7a	29.6±0.8b	44.9±0.5a	29.3±0.6b	34.1
Crude fibre (%)	17.7±0.1c	33.4±0.4ba	17.4±0.5c	23.9±0.6b	13.2
Ether extract (%)	13.9±0.7b	16.6±0.8a	10.6±0.2c	11.7±0.1d	14.3

[abcd] Means values in the same row differed significantly at p<0.05.

confirm the previous findings that the hull of sunflower seed is predominated by crude fibre (Nell *et al.,* 1993). Generally, crude fibre is a heterogeneous chemical entity that includes those carbohydrates that cannot be digested by the animal and therefore do not contribute energy when consumed (Nell *et al.,* 1993). High crude fibre content in the cake therefore reduces its nutritive value and digestibility (Villamide and San Juan, 1998).

Conclusion

The present study provides evidence of the importance of dehulling in improving oil characteristics, yield and cake quality of sunflower. Experimental results show that oil yield could be improved up to 15.4 % when sunflower seeds are dehulled. The physicochemical properties of oil from dehulled seeds were in conformity with recommended values by Tanzania Bureau of Standards. The cake quality (high crude protein content and low crude fibre content) from dehulled seeds was also significantly improved. However, further research is needed to establish the optimum amount of hull that should be left with dehulled seed for facilitating oil extraction without impairing the quality of pressed cake.

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