CHAPTER 2

IMPROVEMENT OF SEED QUALITY THROUGH DRYING AND SIFTING

I. THE EFFECT OF MOISTURE CONTENT ON HULLABILITY

INTRODUCTION

The success of dehulling varies considerably amongst different seed samples. Dorrel & Vick (1997) found that between 40 and 90% of seeds dehulled in samples from different sources. The hull-rich fraction, which is separated from the kernel-rich fraction by aspiration, contains some kernel particles adhering to the hulls and some fine material, which is mainly kernel particles. Oil and protein are lost through these particles and some hulls stay in the kernel-rich fraction due to unhulled seeds. Fine material is undesirable as it is difficult to handle and clogs equipment.

Most industrial dehullers are adjustable so as to alter the impact force on the seed as required. If the impact force is too large, an excessive amount of fine material is produced which increases losses. With a low impact force, the amount of unhulled seed increases which leads to inefficiency and low quality oil cake. Due to the undesirability of fine material and unhulled seed, the huller should be adjusted to the point where the percentage unhulled seed and fine material reaches a minimum. Hullability measurements should be made at this setting.

Different methods of calculating hullability exist. Wan *et al.* (1978) expressed hullability in terms of the percentage unhulled seed and fine material (UFM). For this definition, a smaller percentage indicates a higher hullability. Baldini *et al.* (1994) defined mechanical hull extraction (FH) from which hullability (H) is calculated as follows:

$$FH = ((\text{mass of free hulls})/(\text{mass of sample before hulling})) \times 100\%$$

$$H = (FH/HC) \times 100\%$$

where

$HC = (\text{hull mass}/\text{mass of seed sample}) \times 100\%$ of a manually dehulled sample.

For this definition, higher percentages indicate higher hullabilities.

One factor which influences the hullability of seed is the moisture content (Wan *et al.*, 1978; Tranchino *et al.*, 1984). Evrard *et al.* (1996) found that drying of the seed can increase the hullability. These investigations had several shortcomings. The seed was artificially dried or moistened, fixed huller settings were used and the hullers used were not designed for sunflower seed. According to Dorrell & Vick (1997), such hullers are often the source of problems with the dehulling of sunflower seed. The measurement and calculation of hullabaility by Wan *et al.* (1978), Tranchino *et al.* (1984) and Evrard *et al.* (1996) were done in a way that it can not be related to the method described by Baldini *et al.* (1994). Currently the measurement and calculation of hullability as described by Baldini *et al.* (1994) is accepted widely.

Sunflower seed is stored at a moisture content equal to or less than 10%. Seed used by the industry for processing can thus be expected to contain between 5.5% (the lower level of natural drying) and 10% moisture. The aim of this investigation was to determine the effect of the moisture content of two sunflower seed samples, dried naturally, on hullability, with the huller adjusted for maximum efficiency (lowest UFM).

MATERIALS AND METHODS

Seed of two cultivars produced during 1996/97 on a farm near Heilbron was used for the analysis. The first hullability analysis was done at a mean moisture content of 9.4% as measured with a Bullwark P9 seed analyser (Sinar Africa, P.O. Box 1633, Honeydew 2040). The seed was allowed to dry naturally at room temperature for 10 days. During this period the second, third and fourth hullability analyses were done at mean moisture contents of 8.3, 7.2 and 5.7% respectively.

The hectolitre mass was measured during the first hullability analysis with the Bullwark P9 seed analyser. The thousand seed weight was calculated from the mass of 300 randomly chosen seeds. The seed size distribution was determined by passing approximately 100 g of seed through two sieves, with 3.5 and 3.0 mm slot openings. The hull content was measured from three manually dehulled 2 g seed samples and expressed as a percentage. Mean seed length, width and thickness were measured with a calliper on 100 randomly selected seeds.

The seed was dehulled and separated into a hull-rich fraction, kernel-rich fraction (KRF) and fine material (<2 mm) with a Tecmachine laboratory huller and separator (Tecmachine, Rue Benoit, 42166 Andrézieux-Bouthéon, Cedex, France). Eight seed samples of 12-13 g were dehulled at speeds of 2771, 3068, 3365, 3663, 3960, 4257, 4554 and 4851 revolutions per minute, respectively. The mass of the fine material was measured. Unhulled seeds (seed of which the kernels were completely covered by the hull) were manually removed from the KRF and their mass determined. Next, the relationship between the UFM and huller speed was determined by means of a regression analysis using the equation: $y = ax^{0.5} + bx + cx^2 + d$, with y the UFM, x the huller speed and a, b, c and d constants. The huller speed at which the UFM reached a minimum was considered to be the optimum huller speed. Three seed samples of 12-13 g were dehulled at the optimum huller speed and the mass of the hull and kernel-rich fractions, and the fine material determined. Hullability was calculated as described by Baldini *et al.* (1994) and the data analysed using Statgraphics (Version 5, Statistical Graphics Corporation, Rockville, Maryland USA).

RESULTS AND DISCUSSION

Seed characteristics

The seed characteristics are shown in Table 1. Both samples had relatively high hectolitre masses and thousand seed masses. The size distribution also showed that a high percentage of the seed was large and that high hullability could be expected. The hull content of approximately 31% was also high as the hull content of high oil cultivars is usually below 26%. A high hull content is also associated with high hullability (Baldini & Vannozzi, 1996). Seed dimensions differed between the two samples. Sample no. 1 was relatively short and thick with the thickness about 35% of the length, compared to sample no. 2 where this relationship was about 30%.

Optimal huller speed

Figure 1 shows the relationship between the UFM and the huller speed for the highest and lowest moisture contents of samples nos.1 and 2. A strong relationship between the UFM and huller speed was found for relatively moist seed, but no relationship was evident for dry seed. The optimal huller speed for dry seed was also lower than for wetter seed. If a constant speed of 3800 rpm had been used as in other studies on hullability (Baldini & Vannozzi, 1996; Denis & Vear, 1996), the UFM value of sample nos. 2 at a high moisture content would have been 19.4% which is about twice the UFM values of 9.7% measured at the optimum huller speed. For sample no. 1 this difference was relatively small. Adjusting the huller speed for moisture content seems necessary for efficient dehulling.

Table 1 Characteristics of the sunflower seed samples

Characteristic	------------- Sample no. --------------	
	1	2
Cultivar	SNK 75	NX 1224
Hectolitre mass (kg hl^{-1})	43.9	40.2
Thousand seed mass (g)	64.8	62.9
Size distribution (%)		
<3 mm	15	14
3-3.5 mm	29	41
>3.5 mm	56	45
Hull content (%)	31.0	31.8
Dimensions (mm)		
….Length	10.2	11.6
Width	5.8	5.3
….Thickness	3.6	.3.4

Optimal huller speed was affected by moisture content only (Table 2). The relationship between the seed moisture content and the huller speed is shown in Figure 2. Optimal huller speed increases in a nonlinear way with increased seed moisture content. The optimal speed for the laboratory huller for seed containing between 5.6 and 8.4% moisture is about 3800 rpm.

Unhulled seed and fine material

Moisture content affected the percentage of unhulled seed (Table 2). With a seed moisture content decrease from 9.5 to 5.7% the percentage of unhulled seed halved (Figure 3), indicating that a relatively high seed moisture content can lead to lower quality oil cake due to the presence of more hulls.

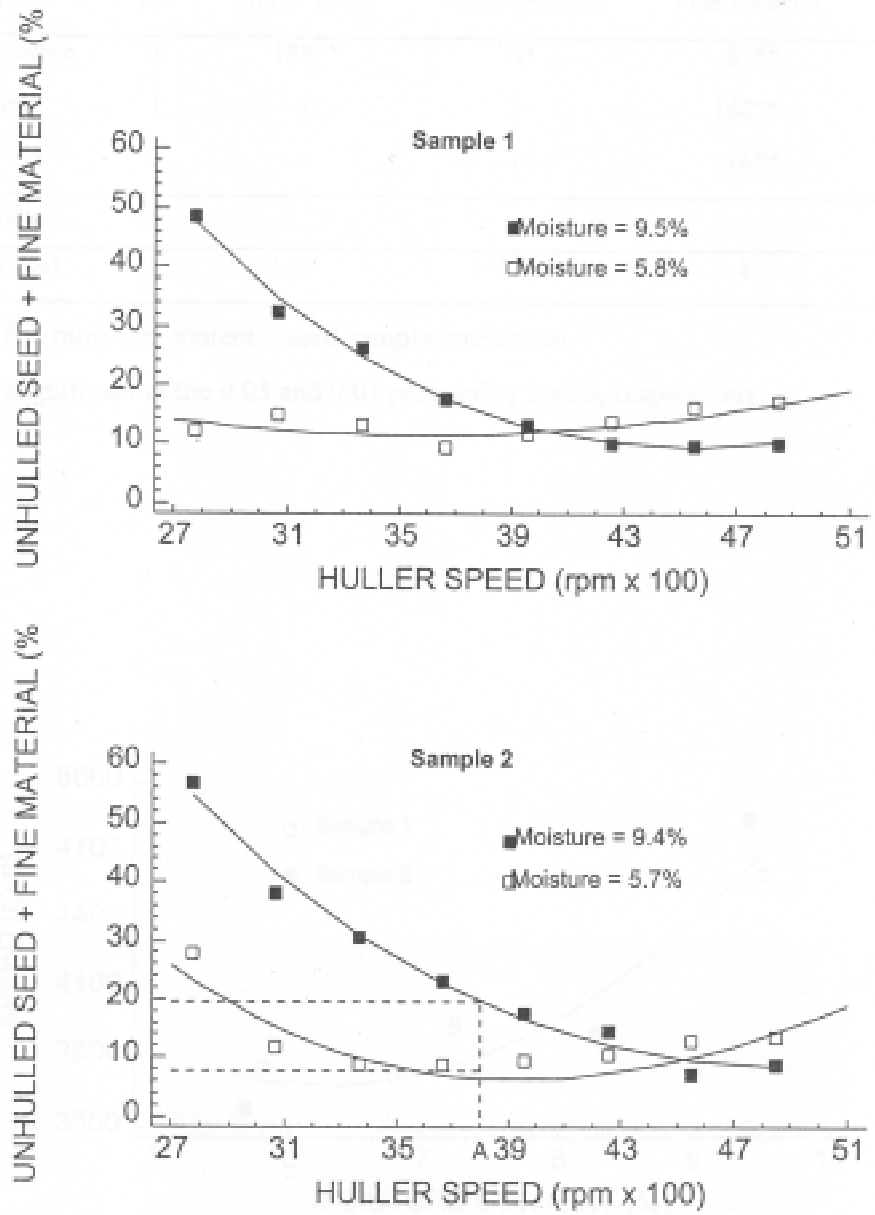

Figure 1 The relationship between the amount of unhulled seed plus fine material and huller speed for relatively wet and dry seed of two sunflower seed samples. Point A on the graph for sample 2 indicates a huller speed of 3800 rpm.

Table 2 Analyses of variance F values for optimal huller speed, percentages of unhulled seed, fine material and hullability as affected by seed sample and moisture content

Source	DF	Huller speed	Unhulled seed	Fine material	Hullability
Moisture	3	188**	4*	83**	11**
Seed	1	2	3	162**	1
M × S	3	-	1	16**	2
Total	23				
CV%		2	37	8	3

M × S = moisture content × seed sample interaction.

**,* Significant at the 0.05 and 0.01 probability levels, respectively.

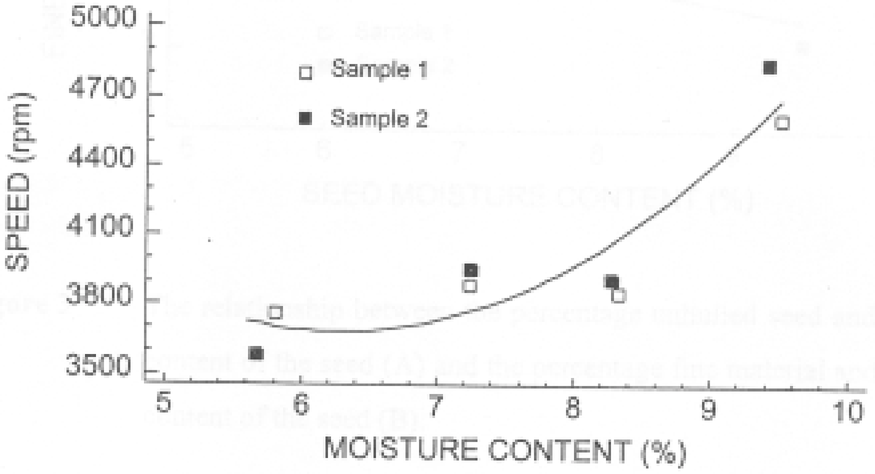

Figure 2 The relationship between the optimal huller speed and the moisture content of the seed.

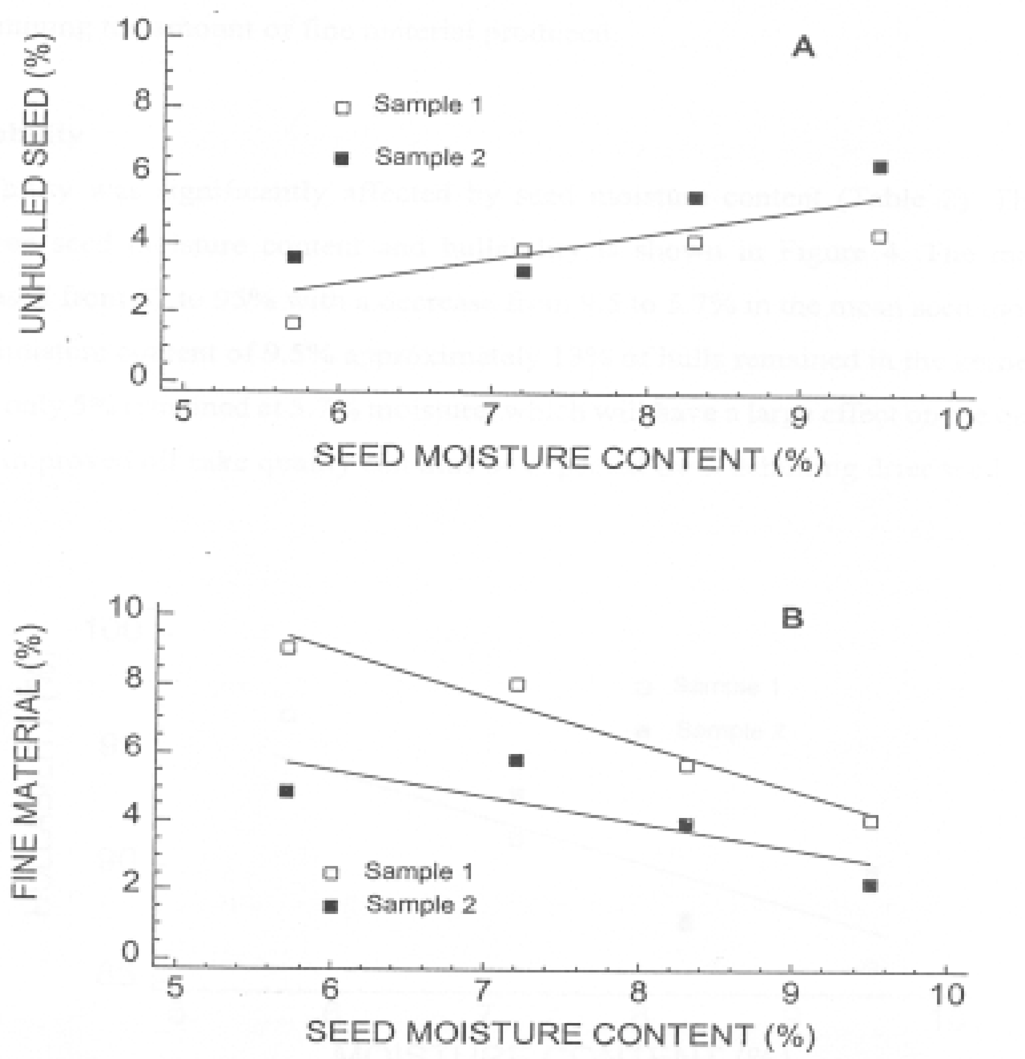

Figure 3 The relationship between the percentage unhulled seed and the moisture content of the seed (A) and the percentage fine material and the moisture content of the seed (B).

The amount of fine material was significantly affected by both sample, moisture content and an interaction between sample and moisture content (Table 2). Sample no. 1 produced 4.1% fine material at 9.5% moisture compared to 9.1% at 5.7% moisture (Figure 3). For sample no. 2 the difference was smaller: at 9.5% moisture only 2.2% fine material was produced abd at 5.7% moisture 4.9% fine material was produced. As the fine material consists mainly of kernel particles, the losses of oil and protein were close to 9 and 4.9% for sample nos. 1 and 2 respectively, at 5.8% moisture. The indication is clear that cultivar plays an important role in determining the amount of fine material produced.

Hullability

Hullability was significantly affected by seed moisture content (Table 2). The relationship between seed moisture content and hullability is shown in Figure 4. The mean hullability increased from 87 to 95% with a decrease from 9.5 to 5.7% in the mean seed moisture content. At a moisture content of 9.5% approximately 13% of hulls remained in the kernel-rich fraction while only 5% remained at 5.7% moisture, which will have a large effect on the quality of the oil cake. Improved oil cake quality can thus be expected from dehulling drier seed.

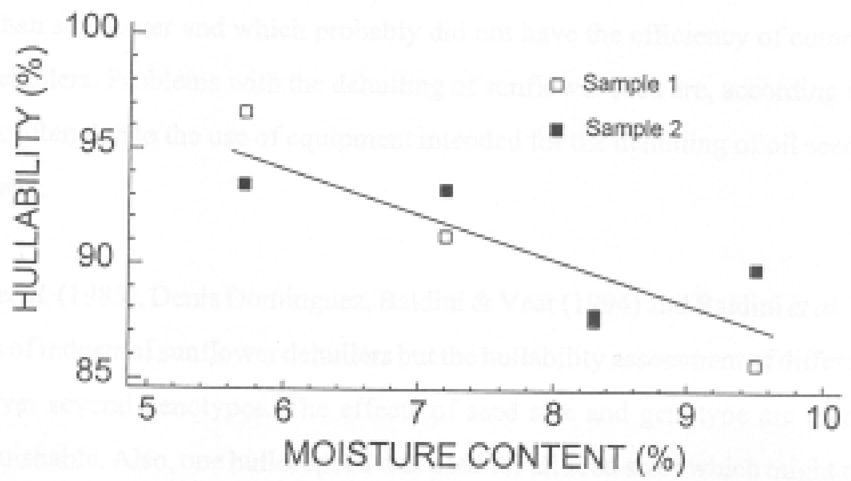

Figure 4 The relationship between hullability and the moisture content of two sunflower seed samples.

Since the production of fine material (and the corresponding losses) also increases as the seed becomes drier it is probably not appropriate to dry the seed too much. Each seed lot should be analysed for hullability and the production of fine material to determine if further drying will increase the efficiency of seed processing. However, if the fine material is separated from the hulls and channeled back to the KRF, drier seeds will benefit oil cake quality due to the inclusion of a smaller percentage of hulls.

II. SEED SIFTING TO INCREASE OIL AND PROTEIN RECOVERY

INTRODUCTION

Several investigations on seed hullability have shown that larger seed are easier to dehull than smaller seed (Wan *et al.*, 1978; Roath *et al.*, 1985; Dedio & Dorrell, 1989; Dedio, 1993; Denis, Dominguez, Baldini & Vear, 1994; Baldini & Vannozzi, 1996; Baldini *et al.*, 1996). Since commercially produced seed comprise a range of sizes which can easily be separated into different size classes, the possibility exists that the efficiency of seed processing could be increased if dehullers are adjusted for optimal dehulling for each size class.

Previous investigations on the hullability of different seed sizes have one or more shortcomings. Wan *et al.* (1978), Dedio & Dorrell (1989) and Dedio (1993) used dehullers intended for grains other than sunflower and which probably did not have the efficiency of commercial sunflower seed dehullers. Problems with the dehulling of sunflower seed are, according to Dorrell & Vick (1997), often due to the use of equipment intended for the dehulling of oil seed crops other than sunflower.

Roath *et al.* (1985), Denis Dominguez, Baldini & Vear (1994) and Baldini *et al.* (1996) used scale models of industrial sunflower dehullers but the hullability assessment of different seed sizes was done over several genotypes. The effects of seed size and genotype are therefore not clearly distinguishable. Also, one huller speed was used for all seed sizes which might not be the optimal for a particular seed size. If differences exist amongst the hullabilities of different seed sizes of a specific cultivar produced at a specific locality, which is the case for commercially produced seed, it cannot be deduced from these results.

The objective of this investigation was to determine whether sifting seed into uniform size classes can improve the hullability by dehulling each class at its optimal huller speed.

MATERIALS AND METHODS

Four samples from seed batches produced from different cultivars at different localities during the 1996/97 season, were used for this experiment (Table 3). Two sieves with slot sizes of 3.0 and 3.5 mm were used to separate part of each seed sample into small, medium and large size classes. Seed moisture content was measured with a Datatec P9 moisture analyser (Sinar Africa, P.O. Box 1633, Honeydew 2040). Mean thousand seed mass was calculated from the mass of 100 randomly selected seeds, sampled in triplicate. Hull content was determined by manually dehulling three samples of 2 g and expressing hull mass as a percentage of the total seed mass (on a fresh mass basis).

Table 3 Sunflower cultivars used in the study and their production localities

SAMPLE	CULTIVAR	LOCALITY
A	CRN 1445	Standerton
B	PAN 7392	Bloemfontein
C	SNK 37	Bloemfontein
D	SNK 48	Standerton

The seed was dehulled and separated using a Tecmachine laboratory dehuller and separator (Tecmachine, Rue Benoit, 42166 Andrézieux-Bouthéon, Cedex, France). To determine the optimal huller speed for each seed sample, between 17 and 18 g were dehulled at huller speeds of 2771, 3068, 3365, 3663, 3960, 4257, 4554 and 4851 revolutions per minute. The mass of the hull-rich, kernel-rich (KRF) and fine material (<2 mm) fractions was determined. Unhulled seed (seed of which the kernel is not visible) were manually removed from the kernel-rich fraction and their mass determined. The dehulling efficiency (unhulled seeds plus fines, UFM) was calculated as: UFM = ((mass of the unhulled seed + mass of fine fraction)/(mass of seed sample prior to dehulling)) x 100%.

The relationship between UFM and huller speed was determined through multiple regression using the equation UFM = $ax^{0.5} + bx + cx^2 + d$; with x the huller speed and a, b, c and d constants. The corresponding huller speed where UFM reached a minimum was considered to be the optimal speed. Accordingly, triplicate samples of between 12 and 13 g were dehulled and separated, and the masses of the different fractions measured. Mean hullability was calculated as described by Baldini *et al.* (1994). Samples of the seed and KRF were chemically analysed for oil and protein content by the PPECB Quality Assurance Laboratory (P.O. Box 433, Silverton 0127), in order to determine the potentially recoverable oil and potential composition of the oil cake.

The potentially recoverable oil (PRO) was calculated as:

$\text{PRO} = (O_{\text{KRF}}) \times (Y_{\text{KRF}})$ where,

O_{KRF} = the oil content of the KRF and

Y_{KRF} = (KRF mass/seed mass used for dehulling)×100, expressed as g oil per 100 g seed.

Analysis of variance was done to determine the effects of seed source and seed size on the measured seed and seed fraction characteristics. Mean values of the different seed samples in the sifted and unsifted form were compared using Student’s t-test with contrast, where the contrast values equalled the mass fraction values in the sifted state. The statistical analyses were executed using Statgraphics (Version 5, Statistical Graphics Corporation, Rockville, Maryland USA).

RESULTS AND DISCUSSION

Sifted samples

The distribution of mass amongst the seed size classes brought about by sieving differed considerably amongst seed sources and also showed a strong locality effect (Table 4). Samples A and D, both from Standerton, showed a relatively even mass distribution amongst the size classes, whilst samples B and C, produced at Bloemfontein, were mainly medium sized. If the seed size classification is done prior to processing, oil extraction plants should be able to accommodate variable mass distributions amongst the seed classes of different seed lots.

Table 4 The mass distribution, thousand seed mass, hullability, production of fine material, potentially recoverable oil (PRO) and the yield and protein content of the kernel-rich fraction (KRF) of the different seed size classes of the seed samples

Size class	------------------------------Sample--------------------------------				
	A	B	C	D	Mean
-------------------------Mass distribution (%)--------------------					
Small	27	24	34	36	30
Medium	40	50	50	36	44
Large	33	26	16	28	26
--------------------Thousand seed mass (g)----------------------					
Small	42.4c[‡]	49.5c	46.9c	46.9c	46.4c
Medium	56.9b	64.1b	61.7b	60.6b	60.8b
Large	69.8a	74.3a	74.9a	83.6a	75.7a
-----------------------------Hullability (%)--------------------------					
Small	46.7c	68.6b	57.7c	42.5c	53.9c
Medium	69.4b	79.3a	74.7b	54.9b	69.6b
Large	77.6a	82.0a	84.2a	71.4a	78.8a
---------------------------Fine material (%)--------------------------					
Small	7.3a	12.8a	6.9a	8.4a	8.9a
Medium	5.8b	9.1b	5.8b	4.6b	6.3b
Large	4.7c	8.1c	4.6c	4.2b	5.4c
------------------------PRO (g per 100 g seed)----------------------					
Small	44.1a	39.4b	37.9a	46.1b	41.9a
Medium	42.8b	39.8b	36.8b	48.7a	42.0a
Large	40.9c	40.6a	35.1c	46.8b	40.8b
---------------------KRF[†] yield (g per 100 g seed)-------------------					
Small	38.3a	28.8b	39.9a	35.6a	35.7a
Medium	35.1b	29.5a	36.8b	33.6b	33.8b
Large	34.1c	28.3b	36.8b	32.2c	32.9c
---------------------KRF[†] protein content (%)------------------------					
Small	32.2c	45.2b	39.2b	32.6b	37.3c
Medium	36.1b	45.7b	43.7a	34.5b	40.0b
Large	41.6a	48.9a	45.9a	38.8a	43.8a

[‡] Means of a parameter followed by different letters in a column differ significantly at $P \leq 0.05$.

[†] Oil-freebase.

Table 5 Analysis of variance F values for the thousand seed mass, hullability, fine material, potentially recoverable oil (PRO) and the yield and protein content of the kernel-rich fraction (KRF) as affected by the sifting of different sunflower seed samples

Source of variation	DF	Thousand seed mass	Hullability	Fine material	PRO	----------KRF[†]------------	
						Yield	Protein
Seed source	3	40**	111**	315**	1087**	1169**	369**
Seed size	2	1096**	293**	306**	29**	211**	80**
S × Z	6	13**	9**	14**	31**	27**	7*
Total	35						
CV (%)		3	4	5	1	1	2

S × Z = Seed source × seed size interaction.

**,* Significant at the 0.05 and 0.01 probability levels, respectively.

[†] Oil-free base.

Sifting of the seed effectively separated it into classes with different thousand seed mass (Table 4). The thousand seed mass was affected by a seed source × seed size interaction, but the effect of seed size dominated the effects of seed source and the interaction (Table 5). The thousand seed mass of the three classes of sample A (CRN 1445 ex Standerton) were smaller than those of the other samples, while the large class of sample D (SNK 48 ex Standerton) was greater than in the other samples. Seed of sample B, which were relatively thin and elongated, had the highest thousand seed mass for the small and medium classes.

Hullability was significantly affected by seed size (Table 5), supporting the findings of Roath *et al.* (1985), Dedio & Dorrell (1989), Merrien *et al.* (1992), Shamanthaka Sastry (1992) and Denis & Vear (1996) that larger seed dehull better than smaller seed. This relationship not only exists across genotypes as shown by Roath *et al.* (1985), Denis Dominguez, Baldini & Vear (1994) and Baldini *et al.* (1996) but also within genotypes (Table 5). A relatively small interaction between seed source and seed size also affected hullability. This was due to the large and medium classes of sample B which had similar hullabilities, whereas it differed significantly for all the other samples (Table 4).

Fine material is undesirable as it consists mainly of kernel material which is removed with the hulls and contributes to the loss of oil and protein. Seed source and seed size caused very similar variation in the production of fine material, with larger seed producing less than smaller seed. The production of fine material was also affected by a small seed source × seed size interaction due to the large and medium classes of sample D which produced similar amounts of fine material (Table 4). Due to the production of less fine material, larger seed are more acceptable for processing than smaller seed. Sample B produced more fine material than any of the other samples and is, in this respect the least acceptable for processing. The relatively high production of fine material in sample B is probably due to the relatively thin and long dimensions of the seed, which appear to break more easily than thicker seed during dehulling.

The potentially recoverable oil was affected by the seed source and a seed source × seed size interaction (Table 5). The small class in samples A and C and the medium class in sample D had the highest potentially recoverable oil (Table 2). Seed source, however, was by far the largest source of variation for the potentially recoverable oil, with large differences amongst the matching size classes of the different samples. Samples D and C had the highest and lowest amounts of potentially recoverable oil respectively.

The yield and protein content of the KRF was mainly affected by seed source and to a lesser extent by seed size and an interaction between these two factors (Table 5). With the exception of sample B, smaller seed classes had greater kernel-rich fraction yields than larger classes (Table 4). Compared to the other seed samples, sample B had very low KRF yields for all size classes. The protein content of the KRF of larger seed classes was higher than that of the smaller classes due to the higher hullabilities of the larger seed. Sample B was the exception with a relatively high KRF protein content and relatively small differences amongst its seed size classes.

Sifted versus unsifted seed

Results from the analysis of variance on the effect of the seed source and sifting of the seed are shown in Table 6. Mean values of the measured seed traits of the unsifted and weighted means of the sifted seed are shown in Table 7. Seed source was the largest source of variation for hullability, although it was also affected by a seed source × sifting interaction.

Table 6 Analysis of variance F values for the hullability, fine material, potentially recoverable oil (PRO), yield and protein content of the kernel-rich fraction (KRF) as affected by seed source and the sifting of the seed

Source of variation	DF	Hullability	Fine material	PRO	-------------KRF---------- Yield	Protein
Seed source	3	63**	85**	638**	1180**	136**
Sifting	1	12**	37**	136**	4	1
S × F	3	33**	44**	157**	55**	5*
Total	23					
CV (%)		3	5	1	1	2

S × F = Seed source x sifting interaction.

**,* Significant at the 0.05 and 0.01 probability levels, respectively.

Table 7 The weighted mean hullability, amount of fine material produced, potentially recoverable oil (PRO) and the yield and protein content of the kernel-rich fraction (KRF) of four sunflower seed samples as affected by seed source and sifting

	Sample				
	A	B	C	D	Mean
	Hullability (%)				
Unsifted	69.5a	73.5b	67.0a	68.5a	69.6a
Sifted	66.0a	77.4a	70.5a	55.0b	67.2b
	Fine material (g per 100 g seed)				
Unsifted	8.1a	8.2b	5.9a	8.5a	7.7a
Sifted	5.8b	9.7a	5.8a	5.9b	6.8b
	PRO (g per 100 g seed)				
Unsifted	40.6b	41.8a	36.7a	41.7b	40.2b
Sifted	42.5a	39.9b	36.9a	47.2a	41.6a
	KRF[†] yield (g per 100 g seed)				
Unsifted	33.2b	29.8a	39.0a	33.7a	33.9a
Sifted	35.6a	29.0b	37.9b	33.9a	34.1a
	KRF[†] protein (%)				
Unsifted	39.3a	45.2a	41.9a	32.9b	39.8a
Sifted	36.8b	46.4a	42.5a	34.9a	40.2a

Means of a parameter followed by different letters in a column differ significantly at $P \leq 0.05$.

[†] Oil-free basis.

The hullability of sample D was 13.5 percentage points lower in the unsifted than in the sifted state, whilst it was 3.9 percentage points higher for sample B. The hullabilities of samples A and C were not affected by sifting. The production of fine material was affected by seed source and a seed source × sifting interaction. For samples A and D, which were produced at the same location, the sifted seed produced respectively 28 and 31% less fine material than in the unsifted state. In contrast, sample B produced 18% more fine material in the sifted than in the unsifted state, while sample C was unaffected.

The potentially recoverable oil was affected by the seed source, sifting and a seed source × sifting interaction, with seed source the dominating source of variation. For samples A and D the potentially recoverable oil was respectively 4.7 and 13.2% higher for the sifted than the unsifted condition. In contrast once again, sample B had 4.5% less potentially recoverable oil in the sifted than in the unsifted state, while sample C was unaffected. The increase or decrease in the potentially recoverable oil is partly due to the differences in the production of fine material. The less fine material produced, the smaller the loss of kernel material and the larger the amount of potentially recoverable oil. The relatively high change in the potentially recoverable oil for sample D can, however, not be fully accounted for by the change in the production of fine material.

The oil free yield of the KRF gives an indication of the oil cake yield that can be expected. This yield was strongly affected by seed source but also by a relatively small seed source × sifting interaction. The KRF yield of sample A sifted was 7.2% higher than for the unsifted state. For samples B and C the KRF yield was approximately 3% lower in the sifted state than in the unsifted state, while the KRF yield of sample D was unaffected by sifting. The changes in KRF yield brought about by sifting are due to changes in hullability and the production of fine material.

The protein content of the KRF is a reflection of the protein content of the oil cake. The KRF protein content was affected by a relatively small seed source × sifting interaction, but the effect of seed source dominated the variation. Sifting did not alter the KRF protein content of samples B and C, whilst it was 6.4% lower in the sifted than in the unsifted form of sample A. In contrast, the KRF of sample D sifted contained 6.1% more protein than in the unsifted state.

CONCLUSION

Seed source is the main source of variation for seed quality. Sifting seed into size classes had only limited success as the potential oil yield of only two of the four samples was increased (by 9%), while for another sample it was decreased. The amount and potential protein content of the oil cake was increased in only one sample. Due to differences in hullability of the seed size classes, sifting resulted in separating the potential oil cake into three classes, with protein content differences of up to 5.5 percentage points.

Results presented in Chapter 2 have been published (Nel, Loubser & Hammes, 1999a; Nel Loubser & Hammes 1999b).