CHAPTER 9

GENERAL DISCUSSION AND CONCLUSIONS

In the past, sunflower breeding was focussed on increasing seed oil content and grain yield, while the seed protein content and hullability received little attention. This lack of focus on the hullability and protein content probably contributed to the problem of poor and variable quality of the oil cake. To be economically sustainable the South African sunflower seed processing industry need seed which not only have an acceptable oil yield but also oil cake with acceptable quality. Seed of acceptable quality will have an oil yield of at least 40 g of oil per 100 g seed and oil cake with at least 40% protein and less than 16% crude fibre at a maximum moisturecontent of 10%. A large proportion of the oil cake produced in South Africa does not meet these standards (Smith *et al.*, 1989).

Results reported in Chapter 2 showed that by natural drying of seed from 9.5 to 5.7% moisture content, hullability improved, leaving only 5% of the hulls in the kernel-rich fraction instead of 13%. The undesirable production of fine material which is lost with the hulls, however, increased simultaneously. It is also clear that the hullability and the production of fine material of seed from different origins (from different cultivars or locations) will respond differently to drying. If the fine material is separated from the hulls and channeled back to the kernel rich fraction, drier seed will benefit oil cake quality due to the inclusion of a smaller percentage of hulls.

It has been observed several times that larger seed tend to dehull more easily than smaller seed (Merrien *et al.*, 1992; Dedio & Dorrell, 1989). Accordingly, the sifting of seed into size classes may also be a means to separate seed into quality classes. Sifting of a seed lot (one cultivar produced at a specific locality) into different size classes and dehulling them separately, showed little benefit for the potentially recoverable oil and protein yield (Chapter 2). Seed sifting, however, proved to be an effective method to produce different potential oil cakes with differentiated qualities from one seedlot. Differences in the protein content of up to 5.5 percentage points between potential oil cakes produced from different size classes have been found, which represent the difference between poor quality oil cake (e.g. 35% protein) and oil cake with acceptable quality (e.g. 40% protein content).

Environmental variables played the major role in determining the physical (hectolitre mass, thousand seed mass, seed size distribution, hullability) and chemical (oil, protein and crude fibre contents) seed composition while cultivars played a less important role, as shown in Chapter 8. Genetic variation was restricted to the 19 available cultivars included in the national cultivar performance trials, which can be assumed to be good performers in terms of grain yield, oil content and disease resistance. Thousand seed mass and hullability were also strongly affected by cultivar and sometimes the cultivar effect dominated over the environmental effects, as shown by the results in Chapter 4. The seed physical characteristics were also affected by a relatively small environment × cultivar interaction. This was due to the change in ranking of cultivars from one environment to another, which does not support the results on hullability of Denis, Dominguez & Vear (1994). The environment × cultivar interaction affected the potential oil and oil cake yield only slightly, due to changes in ranking of cultivars and small effects on the seed protein and crude fibre contents. The stability of certain seed traits from specific cultivars was also evident. The apparent stable hullability of PAN 7392 and stable production of fine material of CRN 1445 over environments give clear indications that the stability of these characteristics is genetically determined. Consequently, it seems possible to genetically improve and stabilize the characteristics in cultivars through breeding, a view also held by Baldini & Vannozzi (1996).

Water stress is one of the major uncontrollable environmental variables that affects the seed yield of sunflower. From literature it is also evident that seed hullability, seed oil and protein content (in order of sensitivity) are all negatively affected by moisture stress during the grain-filling period. While the effects on grain yield and seed oil content have received much attention, the effect of water stress on hullability has not been extensively studied, with mere indications of the effect of wetter and drier conditions having been reported (Merrien *et al.,* 1992; Denis, Dominguez & Vear, 1994; Baldini & Vannozzi, 1996). The results of the mild water stress during the first 25 days of the grain-filling period (Chapter 7) support the results of Baldini & Vannozzi (1996) that water stress reduces hullability. Hullability was, however, less affected than seed yield by water stress. Indications exist that water stress during the last approximate 10 days of the grain-filling period may improve hullability. During this period hull growth has ceased but the kernel is still growing. Water stress will reduce kernel growth and final kernel mass, thereby reducing the kernel content or increasing the hull content of the seed. The general observation is that higher hull content is generally associated with higher hullability. This might explain the results of Denis, Dominguez

& Vear (1994) that seed from a drier environment had a higher hullability than seed from a wetter environment. Taking into account that water stress is probably the major environmental variable affecting sunflower seed yield in South Africa, that its timing and severity can vary considerably in commercial fields and that the effect of a mild stress during the first part of the grain-filling period was investigated, the effect of water stress on seed quality warrants further investigation.

The hypothesis, based on the relationship between hullability and seed size, that hullability can be improved by reducing the plant density, has been confirmed for some cultivars like HV 3037 and SNK 37 (results reported in Chapter 3). To maximise the hullability, the plant density should be as low as possible without affecting yield. This appears to be in the order of 20 000 plants per ha, for the conditions reported in Chapter 3. Emergence of sunflower is often poor due to supra-optimal temperatures in sandy soils (Nel, 1998). To assure that low plant population does not restrict yield, a relatively large amount of seed (up to 50 000 per ha) is planted by farmers. The result is often an uneven spacing of plants and variation in the population density due to uneven emergence. In Chapter 3 only evenly spaced populations were considered. The effect of uneven spacing of plants on seed quality warrants further investigation. Different cultivars should be included in such an investigation as they can differ in their ability to compensate for low plant density under high potential conditions, as shown by Loubser *et al.* (1986).

The results of Chapter 5 show that the hullability was unaffected by N fertilisation within the normal recommended rates of application. The seed protein content increased, however, and the seed oil content decreased with increased nitrogen application, confirming previous research. Through these changes, the protein content of the potential oil cake also increased, while the potential oil yield decreased. Accordingly, nitrogen fertilisation appears to be a mechanism that can be used to manipulate the processing quality of seed by changing the protein content of the seed. Within the range of nitrogen applied, seed yield was more affected than the protein and oil contents of the seed. Only if the sunflower seed price is determined by its oil and protein contents can the economically optimum nitrogen fertilisation rate for seed quality and yield be compared with that of the grain yield per hectare, which is currently the criterion.

Boron fertilisation did not affect seed composition, most likely due to the lack of a serious boron deficiency at the experimental sites (Chapter 6). The fact that the hullability was affected by boron fertilisation at one experimental site can be explained from previous studies on boron. From some experimental evidence and theoretical considerations, Brown & Hu (1997) suggested that the primary and possibly sole function of B is as a structural component of growing tissue. In an overview, Römheld & Marschner (1991) reported that boron is, amongst other structural functions, also related to lignification. From a microscopic analysis of the hull structure, Beauguillaume & Cadeac (1992) concluded that the hullability of seed depends on the structure of the hull, including the degree of lignification of the sclerenchyma cell layer. The yield reduction due to boron fertilisation reported in Chapter 6, indicates that caution should be taken with preventive soil application of boron. Application of boron only after diagnosis of a crop deficiency may be a safer approach. However, the dissimilar seed yield results, the inconsistency of the deficiency and toxicity levels of tissue boron content reported in literature, and the fact that the seed chemical composition and hullability can be affected by boron nutrition, indicate that the boron nutrition of sunflower is still not adequately understood. As the preventive boron fertilisation of sunflower is a standard procedure for many farmers in South Africa, and boron deficiency symptoms are also reported annually, further research into boron nutrition of sunflowers is clearly needed.

The need for an improved seed grading system for sunflower and the possibility of estimating the seed oil and protein contents and the hullability from easily measurable seed characteristics have been discussed in Chapter 8. The relationships between seed characteristics and the seed quality parameters, such as between hectolitre mass and both hullability and amount of fines produced or the seed hull content and hullability, were shown in Chapter 4 and in general confirm the findings of other researchers. Some of these relationships are obvious such as the relatively high positive correlation between the seed oil content and the potentially recoverable oil, or the negative correlation between the seed oil content and the yield of the potential oil cake, or the correlation between both the seed oil and protein contents and the protein content of the expected oil cake. Validation of the equations for estimating the seed oil and protein contents and hullability from easily measurable characteristics, however, has yet to be done. In Chapter 4 it was shown that the relationship between thousand seed mass and hullability of the cultivar PAN 7392 deviated from that of the other cultivars. Validation of the equations for estimating the seed quality parameters should therefore consider cultivars on an individual basis.

A model for estimating the protein and crude fibre contents of the expected oil cake from the seed quality parameters (hullability, oil and protein contents) will be useful. In Chapter 4 it has been shown that simple correlations exist between the oil cake protein and crude fibre contents on the one hand and the hullability and the oil and protein contents of the seed on the other hand (Table 20). Estimating both the protein and crude fibre contents of the potential oil cake from the hullability, seed protein and crude fibre contents appear to be possible. To investigate this possibility, the data reported in Chapters 3 to 7 were combined for regression analyses. The oil and protein contents of the seed were expressed as oil:protein ratios. Multiple linear relationships were derived with the protein and crude fibre contents of the expected oil cake as dependent variables, and the seed oil:seed protein ratio and the seed hullability as independent variables:

$$P = 64.2 - 8.37R + 0.095H \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (1)$$

$$F = 24.1 + 4.56R - 0.235H \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \ (2)$$

where P = expected protein contents of the oil cake expressed as a percentage, on a moisture free and oil free basis
F = expected crude fibre contents of the oil cake expressed as a percentage, on a moisture free and oil free basis
R = seed oil:seed protein ratio
H = hullability

The $R^2 = 0.83$ for equation 1and 0.46 for equation 2, while the mean absolute errors were 1.9% for equation 1and 4.3% for equation 2.

Equations 1 and 2 were used to calculate the threshold relationships between oil:protein ratio and the hullability of seed for an oil cake protein content of 44.4% and a crude fibre content 17.8% which are the moisture free statutory limits. These thresholds are graphically displayed in Figure 6 as solid lines, differing markedly in their slopes and intercepts. Seed with different hullabilities and oil:protein ratios can fall into one of four possible oil cake quality categories. These categories range from where both the protein and crude fibre are within the statutory limits, to where both are outside these limits. It is also clear that for seed with a oil:protein ratio larger than 3.3, it is most unlikely that an oil cake containing 44.4% or more protein (with 0% moisture plus oil), can be produced from it, as hullability can not exceed 100%. It is clear that hullability, seed oil or protein contents should not be judged in isolation to characterise seed quality for oil cake quality purposes, but that it should be seen as interdependent variables.

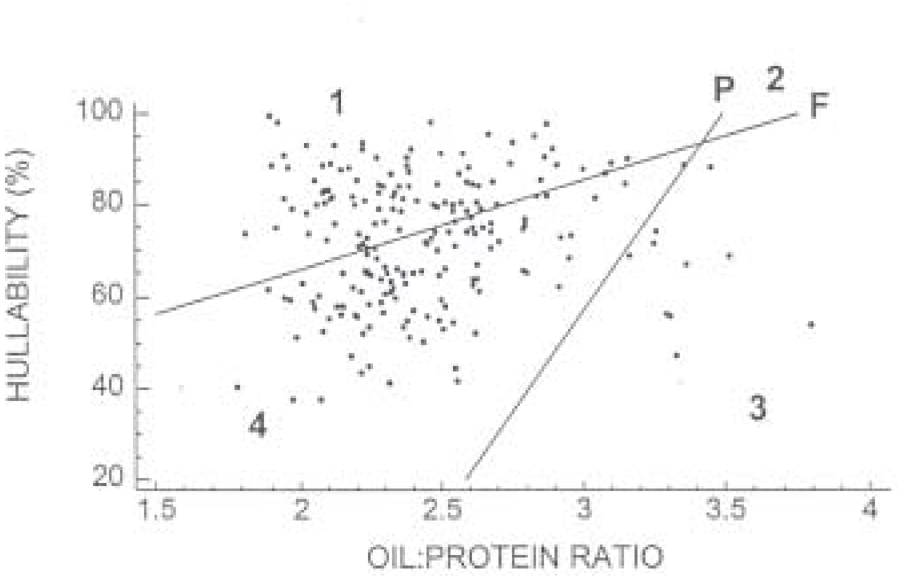

Figure 6 The relationship between hullability and the seed oil:protein ratio of sunflower seed (data points) and the threshold lines for an oil cake protein content of 44.4% (P) and a crude fibre content of 17.8% (F) assuming the oil cake contains no moisture and oil. Quadrant 1: oil cake protein > 44.4%, fibre □̣ı□̃ □̣ □̣Quadrant 2□̣oil cake protein < 44.4%, fibre □̣ 17.8%; Quadrant 3: oil cake protein < 44.4%, fibre > 17.8%; Quadrant 4: oil cake protein > 44.4%, fibre > 17.8%.

The data points in figure 6 represent the 209 seed samples analysed in Chapter 8 (Table 36). As these samples include all the cultivars available in 1999, produced at 11 localities it gives an indication of the quality range of oil cake produced from the national sunflower crop. Approximately 45% of the samples are in quadrant 1, 5% in quadrant 3 and 50% in quadrant 4 assuming that the oil cake contains 0% oil plus moisture. An estimated 95% of these samples will result in oil cake containing 44.4% or more protein (N × 6.25%). An estimated 45% of the samples will result in oil cake containing 17.8% or less crude fibre. This corresponds reasonably well with the 55% commercially produced oil cake samples analysed by Smith *et al* (1989), which contained less than 17.8% crude fibre.

Smith *et al* (1989) stated that sunflower oil cake with less than 10% crude fibre, will be considered as a product of high quality. Less than 1% of the samples analysed in Chapter 8, will be in this category. To produce oil cake with less than 10% crude fibre at 13% moisture and oil, the hullability should be complete and the oil:protein ratio should be extremely low. For example, assuming seed has an oil:protein ratio of 1.8 which is the approximate lower limit for high oil content sunflower, and applying it to equation 2, the hullability should be approximately 99% to produce oil cake with less than 10% crude fibre at 13% oil plus moisture. It appears that high oil content sunflower is unsuitable for producing oil cake with less than 10% crude fibre. Sunflower seed with a relatively low oil:protein ratio may be suitable for producing such oil cake. Open polinated cultivars available during the 1960's had an oil:protein ratio of approximately 1.5:1 indicating that high quality oil cake can be produced from it. This however, has to be confirmed.

Progress was made in identifying several of the factors affecting the processing quality of sunflower seed in South Africa, especially those affecting the oil cake quality. The relative importance of seed conditioning, setting of dehulling equipment, cultivar and environment variables has been shown. The most important environmental variables, which are dufficult to control or manipulate, appear to be water stress, nitrogen supply and possibly boron supply. As these variables were studied independently, it may be worth while investigating what effect treatment combinations and other nutrients would have on seed quality. The importance of plant density, a more easily manageable environmental variable, on seed hullability has been shown. Optimising the seed oil:seed protein ratio through breeding may be the most advisable option for improving seed quality for processing. Efforts to improve seed quality will only be made if they prove to be economically justifiable. One condition for the economic drive for any adjustment to seed quality is that the sunflower seed price should be related to seed quality, something that is currently absent in the South African industry. Some regression models which might be useful for seed quality estimation were presented.