CHAPTER 1

MOTIVATION AND LITERATURE REVIEW

MOTIVATION

Sunflower seed (*Helianthus annuus* L.) is the source of 82% of all edible oil produced in South Africa. The annual production of sunflower seed ranged between 170 000 and 1 100 000 tons from 1989/90 to 1998/99, with a mean of 547 000 tons. From this seed, approximately 219 000 tons of oil were extracted. South Africa, however, is a net importer of vegetable oil. The total oil requirement for 1995/96 was estimated to be 390 000 tons by the Oil Seeds Board. At an annual growth rate of 4% the oil requirement for 2000/01 will be approximately 474 000 tons, of which an estimated 176 000 tons will have to be imported. If locally produced sunflower oil can substitute the imported oil, 987 000 tons of sunflower seed will be needed to satisfy the total oil demand, which will require an area of 897 000 to 1 100 000 ha of sunflower to be grown annually.

Oil cake is the byproduct of sunflower oil extraction and is a source of protein for animal feed blends. Sunflower oil cake, however, is considered to be of relatively poor quality due to a high crude fibre content. The value of sunflower oil cake is equivalent to 72% of the value of soybean oil cake. The relatively poor quality of sunflower oil cake restricts the amount that can be included in feed blends for poultry and pigs. The estimated consumption of sunflower oil cake by members of the Animal Feed Manufacturers Association (AFMA) during 1999 was 273 000 tons (Griessel, 1999), produced from 650 000 tons of seed. The demand for sunflower seed is thus limited by the oil cake quality rather than the demand for oil, which is the main product of the seed.

South Africa experiences a shortage of high quality plant protein to supply in the demand of the animal feed industry. As a result 336 000 tons of oil cake (mainly soybean) was imported annually from 1992/93 to 1996/97 to supplement the local production of 254 000 tons, produced mainly from sunflower (Ebedes, 1996; Ebedes, 1997). The import requirement has since risen to 610 257 tons for 1999/2000 (Griessel, 1999). The annual cost of imports has exceeded R1000 million since 1997, which is approximately twice the amount of money local sunflower farmers receive for their sunflower seed (calculated at R1000 per ton).

The feed value of sunflower oil cake will compare well with that of soybean oil cake if it can be improved through more efficient dehulling (Bekker, 1996). According to Bredenhann (1999) the demand for sunflower oil cake would be 544 331 tons if the crude fibre content can be kept below 14% and the protein above 40%. Approximately 1.3 million tons of seed would satisfy this demand.

If the quality of the locally produced sunflower oil cake can be improved, the possibility of over-production would diminish and the supply of oil and oil cake would be more in balance with the demand. This could lead to savings on imports of oil and probably also oil cake since more sunflower oil cake could replace expensive imported protein sources. Although oil content is the only seed quality parameter sometimes taken into account in trade of sunflower seed, higher quality oil cake may affect seed prices positively for the farmer. It is thus clear that improved sunflower oil cake quality would benefit farmers, the oil and oil cake industry as well as the animal feed industry.

Smith, Hayes & Smith (1989) analysed South African produced sunflower oil cake from different suppliers and found the crude fibre content to range from 11.8 to 24.0% and the protein content from 31.5 to 50.9%, with only 18.2% of the samples with a protein content of more than 40%. They observed that sunflower oil cake can be an important source of protein, on condition that the quality improves. Shamanthaka Sastry & Subramanian (1984) managed to produce oil cake with only 8.3% crude fibre and 53.3% protein from sunflower seed. To produce sunflower oil cake in South Africa containing 14% or less crude fibre and 40% or more protein, seems possible.

According to Fourie (1999) the edible oil industry worldwide is currently under pressure due to a decline in demand and record crops. Edible oil prices have dropped during 1999 to a 23-year low, which led to very low profit margins for sunflower seed processing. Improved sunflower seed quality is a prerequisite for the South African oil industry to be globally competitive (Fourie, 1999).

The challenge to identify the main factors which affect seed hullability and other seed quality parameters, and to manipulate them in such a way as to produce better quality seed for processing, motivated this investigation.

LITERATURE REVIEW

GROWTH AND DEVELOPMENT OF THE SEED

The achene (or seed) of sunflower is borne on the capitulum or head. The head consists of an outer whorl of yellow ray flowers and from 700 to 3000 disk flowers (Seiler, 1997). Each disk flower bears one seed. Anthesis of the disk flowers commences at the periphery of the head and progresses inwards at up to four rows per day. This process takes about 10 days to complete. The seed reach physiological maturity approximately 30 days after anthesis of the first ray flowers, resulting in a shorter period of seed growth for seed at inner positions (Connor & Hall, 1997). Seed closer to the centre also have a lower rate of filling than those at the periphery (Villalobos, Sadras, Soriano & Fereres, 1994). As a result of this shorter period of growth and slower growth rate, seed size decreases from the periphery towards the centre of the head.

The seed comprise of a pericarp (or hull), a true seed coat and a kernel which is mostly embryo. The hull comprises usually between 20 and 26% of the total seed mass. Seed development can be separated into well defined phases. Hull development starts before kernel development, with a typical dry mass of 2 mg at anthesis, and stops growing 14 days later (Connor & Hall, 1997). The kernel starts to grow rapidly approximately 8 days after anthesis and has gained 33% of its final weight when hull growth ceases (Villalobos, Hall, Ritchie & Orgaz, 1996). Due to the differences in pattern and timing of hull and kernel growth, stress during grain filling can alter the mass ratio between the hull and kernel (Connor & Hall, 1997).

Deposition of oil in oil bodies in the embryo begins several days after the start of rapid embryo growth (Villalobos *et al.*, 1996). Consequently, little oil is deposited during the first third of the seed-filling period. Synthesis of oil (of which the greater part is triacylglycerols) is complex, involving metabolic transformations in the cytosol, proplastids and endoplasmic reticulum of the embryo cells (Connor & Hall, 1997). Dihydroxyacetone phosphate derived from glycolysis in the cytosol is converted to glycerol-phosphate, the source of the glycerol skeleton of triacylglycerols, in the cytosol, or it may move across the membranes of the proplastid to form acetyl CoA and malonyl CoA, the primary building blocks of the fatty acid chains (Connor & Hall, 1997). In mature seed, lipids (oil) are mostly triglycerides (97%), phospholipids (2%) and glycolipids (1%) (Connor & Sadras, 1992).

The pattern of protein deposition in seed contrasts that of oil, proceeding in concert with seed growth so that the concentration of protein in the seed dry matter remains fairly constant over time (Goffner, Cazalis, Percie du Sert, Calmès & Cavalie, 1988). Protein deposition in the seed, its subcellular localization, its control, and the partitioning of protein among the various functions such as enzymes and storage, are not fully understood and requires further investigation (Connor & Hall, 1997).

SEED HULLABILITY

Russian breeders succeeded in increasing sunflower seed oil content from approximately 30% in the 1920s to 50% in cultivars available in the mid-1960s (Fick & Miller, 1997). Approximately two thirds of this improvement was due to a decrease in hull content and the remainder to an increase in the kernel oil content (Gundaev, 1966). Roath, Snyder & Miller (1985) mentioned that selection for high seed oil content may have resulted in inadvertent selection for seed which is more difficult to dehull. Investigations of the effect of poor hullability on the quality of oil cake started during 1990 in Europe as a result of the increased world demand for oil cake (Evrard, Burghart, Carré, Lemarié, Messéan, Champolivier, Merrien & Vear, 1996).

The main reason for dehulling sunflower seed before processing is to obtain oil cake with an increased protein content and a decreased crude fibre content. Other advantages are that the efficiency of processing increases as the movement of unnecessary mass through the oil extraction system is reduced and the oil contains less wax which needs to be removed. With dehulled seed, wear of the expeller is reduced (Tranchino, Melle & Sodini, 1984; Ward, 1984; Shamanthaka Sastry, 1992; Dorrell & Vick, 1997).
Various types of dehulling equipment are available. The impact type is the most popular in the processing industry. The impact dehuller feeds seed onto the centre of a horizontally rotating impeller fitted with outward directing blades or grooves. The seed is accelerated outwards along the blades and collides with the static wall where the hull is cracked. The loose hulls are then

separated from the dehulled kernels, partially dehulled seed and some unhulled seed by passage through a system of beds containing aspirated screens, to produce the kernel-rich fraction.

Seed from different origins differ in their hullabilities (Dorrell & Vick, 1997) and it is often necessary to adjust dehullers to increase or decrease the impact velocity of the seed. It is, however, difficult to achieve an optimum balance between excessive dehulling, which leads to loss of oil rich material, and insufficient dehulling, which reduces efficiency (Dorrell & Vick, 1997). In this regard, Shamanthaka Sastry (1992) showed that increased dehuller speed also increased both the amount of dehulled seed and fine material. The fine material consists mainly of kernel particles which are removed with the hulls through aspiration. Excessive dehulling therefore leads to a loss of oil and protein. Insufficient dehulling, due to a too slow dehuller speed, leads to inefficiency. Complete separation of hulls and kernels, however, is also not desirable for the extraction of oil with a mechanical screw press as a small amount of hull enhances the extraction process (Morrison III, Akin & Robertson, 1981).

After dehulling, most of the oil is squeezed from the kernel-rich fraction whilst the remainder is extracted with a volatile organic solvent (hexane). The residue is the oil cake. The composition of the oil cake depends on the amount of hull removed, as well as the composition of the kernels.

CALCULATION OF HULLABILITY

Different methods for calculating hullability have been described. Hullability is calculated after the dehulling of a seed sample and the separation into the kernel-rich fraction, a hull-rich fraction and in some cases also fine material. Dedio & Dorrell (1989) calculated hullability as follows:

Hullability = (mass of completely dehulled kernels in the kernel-rich fraction/
mass of seed sample before dehulling)   100%

For this definition, a high percentage indicates a high hullability. In contrast, Wan, Baker, Clark & Matlock (1978) defined hullability as the sum of the mass of unhulled seed and fine material passing through a 2.4 mm screen, expressed as a percentage of the seed sample. For this definition, a smaller percentage indicates a higher hullability.

European researchers also take hull content into account when calculating hullability. Tranchino *et al.* (1984), Merrien, Dominguez, Vannozzi, Baldini, Champolivier & Carré (1992), Baldini, Vannozzi, Cecconi, Macchia, Bonari & Benvenuti (1994), Denis, Dominguez, Baldini & Vear (1994) and Baldini & Vannozzi (1996) all defined hullability as:

Hullability = (FH/HC)   100%

where FH = (mass of hulls removed during dehulling/mass of seed sample before dehulling) 100% and HC = (mass of hulls/mass of seed sample)   100% of a manually completely dehulled sample.

SEED CHARACTERISTICS RELATED TO HULLABILITY

Several seed characteristics like oil, moisture and wax content, hull content, hull thickness, seed size and seed density all affect the hullability of seed. Correlation coefficients and the mathematical relationships between the seed characteristics and hullability, however, vary considerably amongst environments and genotypes.

Seed oil content

The general finding of researchers is that higher seed oil content is associated with lower hullability of the seed (Roath *et al.*, 1985; Dedio & Dorrell, 1989; Beauguillaume & Cadeac, 1992; Merrien *et al.*, 1992; Dedio, 1993; Denis, Dominguez, Baldini & Vear, 1994; Baldini & Vannozzi, 1996; Baldini, Vannozzi, Macchia & Bonari, 1996; Denis & Vear, 1996). One of the aims of sunflower breeding programmes is to increase the seed oil content of cultivars. If the negative relationship between oil content and hullability stays valid in future and the oil content increases above the current level, hullability will decline, resulting in declining oil cake quality. Baldini & Vannozzi (1996), however, found that this negative relationship is not universal since the cultivar Euroflor, in contrast with other cultivars, has a high oil content and a high hullability. According to Baldini *et al.* (1994), no relationship exists between the oil content of the kernel and the hullability of the seed. The absence of any relationship was confirmed by Denis, Dominguez & Vear (1994).

Hull content and hull thickness

Most findings indicate that hullability increases with increased hull content of the seed (Baldini *et* *al.*, 1994; Denis *et al.*, 1994; Baldini & Vannozzi, 1996). Roath *et al.* (1985), however, found no clear relationship, whilst Dedio (1982) found a negative relationship.

According to Beauguillaume & Cadeac (1992) hull thickness has no relationship with hullability, since the cultivar Euroflor has both a thin hull and high hullability. The microscopic investigation of Beauguillaume & Cadeac (1992) has shown that the frequency of parenchyme layers in the sclerenchym of the hull is related to hullability. According to Denis, Dominguez, Baldini & Vear (1994) and Denis & Vear (1996) the negative relationship between the seed oil content and hullability is probably explained by the positive relationship between the hull content and hullability, as well as the negative relationship between the hull content and oil content of seed found in other studies. Morrison III *et al.* (1981) concluded that the adherence of the hull to the kernel, the width of the hull and the thickness of the lignified layer of the hull could all affect the dehulling process.

Seed size

Larger seed usually dehull more easily than smaller seed (Roath *et al.*, 1985; Merrien *et al.*, 1992; Shamanthaka Sastry, 1992). Dedio & Dorrell (1989) found seed size to be the most important determinant of hullability. Due to these differences in hullability, Popova, Serdyuk & Kopejkovskij (1968) suggested that seed should be separated into fractions of uniform size and moisture content. Denis & Vear (1996), however, showed that the relationship between the thousand seed weight (which indicates the seed size) and hullability varies amongst localities. Large seed from one area might have a lower hullability than small seed from another.

Popova *et al.* (1968) found that smaller seed have thinner hulls with more flexibility than larger seed. Increased moisture content increased the flexibility, and an increased force was then needed to break the hull. The hull was easier to crack when the force was applied to the longest axis of symmetry of the seed. The thin hull of cultivars with a high oil content contains more wax than the hull of low oil content cultivars (Morrison III *et al.*, 1981). These thin hulls are also tightly held to the kernels, being connected with more fibres.

Seed density and hectolitre mass

Tranchino *et al.* (1984) found that seed of cultivars with a low density are easier to dehull due to a larger air space between the kernel and the hull, compared to seed of cultivars with a higher density. The hectolitre mass is an indirect measure of seed density and, according to Tranchino *et al.* (1984), seed with a hectolitre mass above 40 kg hl^{-1} are difficult to dehull. Negative relationships between hectolitre mass and hullability were also found by other researchers (Dedio & Dorrel, 1989; Dedio, 1993; Baldini & Vannozzi, 1996; Baldini *et al.*, 1996).

Genotype

According to Merrien *et al.* (1992) and Baldini & Vannozzi (1996) genotype is the main source of the variation in hullability. In their investigation on the hullability of different genotypes, Baldini & Vannozzi (1996) found that some genotypical traits, such as the length of the period from emergence to flowering and from flowering to physiological maturity, correlate negatively with hullability.

Seed moisture content

Several researchers found that hullability increases with decreasing seed moisture content (Beloborodov, Kuznetson & Matsuk, 1970; Wan *et al.*, 1978; Tranchino *et al.*, 1984). This increase in hullability is due to a decrease in the flexibility of the hull with decreasing moisture content (Popova *et al.*, 1968).

During dehulling, some fine material, mainly kernel particles, is also produced. This fine material is undesirable as it is lost with the hulls. Both Wan *et al.* (1978) and Tranchino *et al.* (1984) found that the amount of fine material increased and the amount of unhulled seed decreased with declining seed moisture content. Tranchino *et al.* (1984) found that the mass of unhulled seed plus fine material reached a minimum at a seed moisture content of 3%, which was considered the optimum moisture content for dehulling with a laboratory air-jet impact dehuller. However, seed moisture content at stages other than during dehulling also affects hullability. In this regard, Baldini & Vannozzi (1996) found a negative relationship between hullability and the seed moisture content at harvest.

Seed wax content

Results of studies on how wax content of the seed affects hullability are contradictory. Roath *et al.* (1985) and Dedio (1982) found negative relationships whilst Dedio (1993) found a positive relationship between the wax content and the hullability of seed. Morrison III *et al.* (1981)

suggested that the wax content of the hull determines the force needed to break the hull.

ENVIRONMENTAL FACTORS AFFECTING HULLABILITY

Seed produced in drier locations tend to have higher hullabilities than that produced in wetter localities. Denis, Dominguez, Baldini & Vear (1994) found the mean hullability of seed produced in a relatively dry region of Spain to be 83.1%, which was twice as high as the 41.5% seed hullability produced in the relatively wet conditions of France. Water stress increases hull thickness which leads to increased hullability, according to Leprince-Bernard (1990).

Merrien *et al.* (1992) found the hullability of cultivars to be relatively stable over seasons at a specific locality. They also attributed the change in hullability from one season to another and between localities to the rate of drying of the seed after physiological maturity has been reached. Seed from regularly irrigated sunflower crops had higher hullabilities than seed from less frequently irrigated treatments. To a lesser extent, nitrogen fertilisation also affects hullability. Baldini & Vannozzi (1996) found that the hullability of two cultivars increased due to high nitrogen and water supply, whilst the hullability of a third (long season) cultivar improved due to minor nitrogen and water shortages.

Hullability is also affected by an environment genotype interaction, in which the effect of the genotype was found to predominate (Baldini & Vannozzi, 1996; Denis & Vear, 1996). Evrard *et al.* (1996) also declared that the genetic effects on hullability are always larger than the environmental effects, but Denis, Dominguez & Vear (1994) found the environmental effects to predominate.

FACTORS AFFECTING SEED COMPOSITION

Nitrogen and phosphorus fertilisation

South African research indicates that the effect of fertilisation on seed composition depends on the fertility level of the soil. Blamey & Chapman (1981) found that nitrogen fertilisation of soil with a low fertility status increased seed protein content and that phosphorus fertilisation decreased seed protein, whilst the opposite effect occurred with oil content. Fertilisation with nitrogen and phosphorus, however, increased both oil and protein yield per unit land area. Loubser & Grimbeek (1985) also found that increased nitrogen fertilisation decreased seed oil content and increased protein content while phosphorus fertilisation had no effect, probably due to sufficient available phosphorus in the soil to ensure high oil content. Smith, Smith, Bender & Snyman (1978) found no response of the seed oil and protein contents to liming or nitrogen, phosphorus and potassium fertilisation, but they do not mention the fertility status of the soil.

Research outside South Africa also shows that seed composition is affected by fertilisation. Steer, Coaldrake, Pearson & Canty (1986) found that seed oil content declined and seed nitrogen content increased with increased nitrogen fertilisation. upina, Saka , Plesni ar, Pankovi , Joci & Navaluši (1992) concluded that increased nitrogen fertilisation inhibited oil synthesis whilst the synthesis of protein was stimulated.

The glasshouse trials of Steer, Hocking, Kortt & Roxburgh (1984) showed that high N supply during grain filling resulted in seed with low oil and high nitrogen contents. High nitrogen supply before and low nitrogen supply after anthesis resulted in seed with a low nitrogen content, mainly due to low nitrogen in the kernel. Esendal & Aytaç (1996) found seed oil contents of 41.6 and 39.8% for nitrogen applications of 0 and 50 kg ha^{-1} respectively, with no effect on the seed protein content. Mészáros & Simits (1992), who applied nitrogen to the leaves during different growth stages, also found a decrease in seed oil content with increasing levels of nitrogen application. Oil and grain yield per hectare increased with increased amounts of nitrogen.

Results of studies on the effect of nitrogen source on seed oil and protein contents are contradictory. Seed produced in a glasshouse with nitrate contained 50% oil while seed produced with urea as the nitrogen source contained only 41% oil (Hocking & Steer, 1983). The thousand seed mass of the plants receiving nitrate was higher than for plants which received urea. In contrast, Esendal & Aytaç (1996) found no difference in the oil and protein content of seed produced in a field trial with urea, ammonium or nitrate as sources of nitrogen.

Boron fertilisation

Boron fertilisation of sunflower on soil with a pH (KCl) < 4.9 resulted in increased yield and seed oil content of two cultivars (Blamey & Chapman, 1982). Concomitant with the increased oil content, protein content for one cultivar was significantly decreased by B fertilisation. The decrease in protein content was not as great as the increase in oil brought about by B fertilisation, presumably indicating a change in the kernel to hull ratio. In this trial, liming resulted in a slight increase in the seed protein content while the oil content was unaffected.

Plant density

Results of studies on the effect of plant density on seed composition are contradictory. Allesi, Power & Zimmerman (1977), McWilliam & English (1978), Miller & Fick (1978), Steer *et al.* (1986) and Esechie, Elias, Rodriguez & Al-Asmi (1996) all found no effect of plant density on the seed oil and protein content. Thompson & Fenton (1979) and Mathers & Stewart (1982) found a small response of seed composition to plant density (ranging from 2.5 to 15 plants m^{-2}). Stoyanova (1974), Jones (1978), Gubbels & Dedio (1986), Majid & Schneiter (1987) and Zaffaroni & Schneiter (1991) on the other hand, all found that oil content increased with increased plant density.

Robinson, Ford, Lueschen, Rabas, Smith, Warnes & Wiersma (1980) found that the mean oil content of both low and high oil content cultivars produced at six localities increased from 37.5 to 42.2% when plant density was increased from 1.7 to 6.2 plants m^{-2}. Jones (1984) also found a small increase in seed oil content by increasing the density from 2.5 to 4.5 plants m^{-2}. Seed oil contents of 40.3 and 42.1% were measured by Ortegón & Díaz (1997) for densities of 3.1 and 6.3 plants m^{-2}. This difference in oil content was mainly due to different hull contents. Villalobos *et al.* (1994) also found that oil content increased while the single seed weight decreased with increased plant density. The absolute amount of oil per seed showed a relatively small decrease compared to the decrease of the single seed weight.

A decrease in oil content due to an increase in plant density has also been observed. Esendal & Kandemir (1996) increased the plant population by decreasing the row width to change the plant density from 3.5 to 6.6 plants m^{-2} and found that the seed oil content decreased from 41.8 to 37.6%. The protein content also decreased from 17.4 to 15.3% whilst the kernel content decreased from 73.1 to 72.1%.

After analysing various trials on the response of seed composition to plant density, Connor & Hall (1997) stated that one interpretation of the results is that there is a ceiling to the absolute amount of oil that can be stored in a seed. If availability of carbon during seed filling exceeds the capacity for oil deposition, carbon is allocated to other seed components and the seed oil concentration is diluted. At typical commercial densities, the various effects of density on seed oil content may be hard to establish (Steer *et al.*, 1986).

Shade

By decreasing the radiation intensity of the sun by 45% using shade netting during the grain-filling period, Andrade & Ferreiro (1996) found that the seed oil content decreased from 48.1 to 41.9% and that the protein content increased from 17.2 to 20.6%. Seed yield, however, was affected the most as it decreased from 74 to 48 g per plant.

Water stress

Talha & Osman (1975) found that water stress during the vegetative as well as the reproductive growth periods decreased the seed oil content from 31.9 to 24.7%. It seems, however, that water stress during the vegetative period has a larger affect on the oil content than on the seed protein content. Alessi *et al.* (1977) and Hall, Chimenti, Vilella & Freier (1985) found that water stress during or after anthesis decreased the seed oil content. Muriel & Downes (1974) recorded a decrease in seed oil content from 45 to 39% due to water stress after anthesis. Hall *et al.* (1985) declared that water stress during grain filling allocates captured carbon to components other than oil.

This is supported by the results of Blanchet & Merrien (1990) who found that severe drought during the grain-filling period altered the oil-to-protein ratio from 2.9 for non-stressed seed to 1.6. Goffner *et al.* (1988), who applied abscisic acid to isolated seed lobes, found that incoming ^{14}C-sucrose was translocated from lipid to protein synthesis. This indicates that the larger amount of abscisic acid which is produced in the leaves of stressed plants is translocated to the seed and thus contributes to the decline in the seed=s oil-to-protein ratio (Connor & Sadras, 1992).

The results of Sionit, Ghorashy & Kheradnam (1973) are in contrast to the findings that water stress affects seed oil content. In an experiment conducted in pots, where the soil water potential was kept at different levels for different treatments, yield was dramatically affected but seed oil content and thousand seed weight were unaffected.

Temperature

Results differ with respect to the effect of temperature on seed composition. Canvin (1965) found that the oil-to-protein ratio dropped from 2.6 to 1.8 with an increase in temperature from 10 to 27 C, due to a large increase in protein content associated with the rise in temperature. In a field trial with different planting dates, the highest seed oil content was found for the growing season with the highest mean temperature (Remussi, Saumell & Vidal Aponte, 1972).

Goyne, Simpson, Woodruff & Churchett (1979) found a negative and a positive relationship between the temperature of the growing season and the seed oil content for an open pollinated and a hybrid cultivar respectively. Although these oil content temperature relationships were significant, Goyne *et al.* (1979) concluded that other plant and environmental factors are more important than temperature for the determination of the final seed oil content. In a controlled environment study, Harris, McWilliam & Mason (1978) found that higher temperatures during grain filling resulted in lower seed oil content. They declared that temperature is only one amongst several factors, such as water stress, which affect seed oil content under field conditions. Using planting dates as treatments, Keefer, McAllister, Uridge & Simpson (1976) concluded that seed oil and protein content are not affected by temperature during the grain filling stage.

No South African publications on the hullability of sunflower seed could be found and only a few on the seed composition of out-dated cultivars. The effect of local conditions and current cultivars on the hullability and composition of sunflower seed is currently unknown.