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Some Physical and Morphological Properties of Wild Sunflower Seeds

E.E. Perez[1]; G.H. Crapiste[2]; A.A. Carelli[2]

[1]Facultad de Ingeniería, Universidad Nacional del Centro de la Pcia de Buenos Aires, Av. del Valle 5737, B7400JWI Olavarría, Argentina; e-mail: eperez@fio.unicen.edu.ar
[2]Planta Piloto de Ingeniería Química (Universidad Nacional del Sur-Consejo Nacional de Investigaciones Científicas y Técnicas), Camino La Carrindanga, km. 7, CC 717, 8000 Bahía Blanca, Argentina; e-mail of corresponding author: acarelli@plapiqui.edu.ar

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As part of a study to characterise and examine the use of wild sunflower species (*Helianthus petiolaris* Nutt), some physical properties and morphological characteristics of seeds from different locations in Argentina were determined. The oil content ranged between 27% and 30% (wb) and the moisture content varied from 8·9% to 10·4%. The average length, width, and thickness of the seed, measured with a micrometer, were 4·5, 2·02, and 1·2 mm, respectively. The calculated mean values of seed equivalent diameter, surface area, and sphericity were 2·25 mm, 16·2 mm^2, and 0·48, respectively. The bulk and true densities measured with a hectolitre tester and by picnometry, respectively, were 350 and 399 kg/m^3. The angle of repose ranged between 28·6° and 30·2°. The morphological characteristics as well as the hull thickness and percentage were also evaluated by scanning electron microscopy. The hull thickness and percentage had mean values 0·07 mm and 21%, respectively. Achenes presented straight and double hairs and a morphological study showed a pericarp structure with an amorphous and lignified fibre layer and air cavities between the inner parenchyma and the cotyledon.

1. Introduction

Helianthus petiolaris, whose common name is Prairie Sun, is an annual wild sunflower species that originated in North America. It is an erect annual species with yellow flowers that belongs to the Compositae family (Asteraceae) (Seiler, 1994, 1997). This adventitious species is in the process of naturalisation in Argentina and it is widespread in the semi-arid lands of Córdoba, San Luis, La Pampa, and Buenos Aires provinces. It grows overlapping about 50% of the sunflower crop area (*Helianthus annuus*), so that could bring as contaminants in forage seed lots (Poverene *et al.*, 2004).

This wild sunflower is resistant to diseases, insect pests and drought. Such desirable properties may be exploited to improve sunflower crops (*H. annuus*) by transferring these characteristics through plant breeding hybridisation. It is very important to expand the agronomic and genetic information on this species, as it could represent an alternative raw material to obtain oil, meal and oleochemical products (Poverene *et al.*, 2004; Seiler, 1994, 1996, 1997).

A few reports on the genetic characteristics and seed composition of *H. petiolaris* have been published (Dorrell & Whelan, 1978; Seiler, 1994, 1996, 1997). In a recent paper, quality and nutritional data was presented for *H. petiolaris* oils and meals (Perez *et al.*, 2004). The oil had less quality and stability due to the major unsaturation (a high concentration of oleic and linoleic acids, 12–29% and 74–80%, respectively) and the lower concentration of antioxidant components. The phospholipid content was significantly lower than in industrial crude sunflower oils (Crapiste *et al.*, 1999; Brevedan *et al.*, 2000). The meal had lower protein content, although the other important parameters as available lysine, gross energy, and digestibility compared favourably with those for cultivated sunflower meals. The results showed the potential use of these meals for animal feeding (Perez *et al.*, 2004).

The aim of this study was to determine some morphological and physical properties of *H. petiolaris* seeds that are often required to develop equipment for handling, storage, transportation, drying, and other processes involving the seed.

Notation

D_e geometric mean diameter, mm	W seed width, mm
L seed length, mm	Φ sphericity of seed
S seed surface area, mm^2	
T seed thickness, mm	

2. Materials and methods

2.1. *Material*

Capitulums from spontaneous population of *H. petiolaris* were randomly collected from edge rural road during the summer season (February–March), in different regions of Argentina: south of Córdoba (sample A), east of La Pampa, and west of Buenos Aires (sample B) and northeast of La Pampa (sample C). The achenes were separated manually from their heads and selected, rejecting the immature or underdeveloped seeds. They were packed in hermetic glass vessels and stored at 5 °C until use.

2.2. *Physical properties*

Samples were randomly selected to determine their moisture content according to IUPAC 1·121 method (IUPAC, 1992), by oven drying at 105 °C until constant weight. The whole seeds were ground and extracted with *n*-hexane (b.p. 68–72 °C) in a Soxhlet apparatus, following IUPAC Standard Method 1·122 (IUPAC, 1992). A nitrogen stream removed the solvent contained in extracted oils and residual meals. The oil was weighed to calculate the extraction yields.

Seeds were randomly drawn from the seed pool in order to determine their size and shape. For each individual seed, three principal dimensions: length L, width W, and thickness T, all in mm, were measured using a micrometer (least count 0·01 mm), excepting sample C, which was evaluated by scanning electron microscopy. The equivalent diameter D_e in mm and sphericity Φ were determined using the following expressions (Gupta & Das, 1997; Tunde-Akintunde & Akintunde, 2004):

$$D_e = (LWT)^{1/3} \tag{1}$$

$$\Phi = (LWT)^{1/3}/L \tag{2}$$

The seed surface area S in mm^2 was calculated by analogy with a sphere of the same geometric mean diameter as

$$S = \pi D_e^2 \tag{3}$$

The dynamic angle of repose was determined by using a plywood box (0·3 m of length, width and height), which had a removable front panel. The box was filled with the seeds and the front panel was quickly removed, allowing the seeds to flow to their natural slope. The angle of repose was calculated from the measurements of the horizontal displacement distance of the seeds and the height of the heap.

To evaluate the seed mass, three groups of 100 seeds were randomly selected from the bulk and weighted on an electronic balance with 0·001 g accuracy, and the weights were averaged.

The bulk density considered as the ratio of the mass seed sample to its total volume was determined, by using a standard 250-m*l* equipment with a piston for air displacement. The true density was determined by means of an electronic balance and a picnometer, employing vaseline as the displacement liquid.

2.3. *Microscopy*

The whole seeds or achenes were adhered to a cover slip, coated with a thin gold film in a sputter coater (Pelco 9100) and observed in a scanning electron microscope (model 35 CF, Jeol, Tokyo, Japan) at 5 kV. Longitudinal sections of achenes were sliced with a razor blade, after being plunged into liquid nitrogen to ensure the maintenance of their internal structure, and analysed by microscopy using the same procedure and magnification ranges between ×20 and ×3200. The hull thickness and percentage were evaluated by microphotography analysis.

3. Results and discussion

Table 1 summarises the general characteristics of *H. petiolaris* seeds. The moisture content varied from 8·9% to 10·4%. The oil yield ranged from 27% to 30% (wet basis), representing 60–70% of the amount industrially obtained from cultivated sunflower seed

Table 1
Characteristics of *Helianthus petiolaris* seeds

Colour	Brown, stained
Shape	Oval
Length L, mm	4–6
Width W, mm	1–3
Thickness T, mm	1–2
Weight/10^3 seeds, g	6·4–7·3
Bulk density, kg/m^3	346–355
True density, kg/m^3	376–420
Angle of repose, deg	28·6–30·2
Moisture content, %	8·9–10·4
Oil content, % wb	27–30

Table 2
Size distribution of *Helianthus petiolaris* seeds

	Sample		
	A	*B*	*C*
Length L, mm	4·71±0·16	4·71±0·32	4·104±0·049
Width W, mm	2·37±0·09	1·73±0·16	1·959±0·030
Thickness T, mm	1·45±0·08	0·95±0·13	—
Geometric mean diameter D_e, mm	2·53±0·25	1·98±0·19	—
Sphericity Φ	0·54±0·02	0·42±0·02	—
Surface area S, mm^2	20·1±1·10	12·3±0·67	—

Number of samples A and B, $n = 25$; sample C, $n = 176$.

varieties (Perez *et al.*, 2004). The mean 1000-seed mass was 6·84 g. A similar result had been obtained for plant populations in the USA, averaging 7·3 g/1000 seeds in weight, with a 3·5–4·5 mm length range (Dorrell & Whelan, 1978). The mean true and bulk densities were 350 and 398 kg/m^3, respectively. This implies that the achenes are lighter than water so that a cleaning process by floating can be designed to separate seeds from heavier fractions.

The dimensional parameters, surface area, sphericity and geometric mean diameter of each sample are given in Table 2. The results are expressed as the means of n determinations with 95% confidence intervals. The seed size was in the same range as those reported by Seiler (1997) for this species: 2–7 mm length and 1–2 mm width.

In sample B, about 72% of the seeds were large ($L>5$ mm), whereas about 16% were medium-sized ($4{\cdot}5 \leqslant L \leqslant$ mm), and 12% small ($L<4{\cdot}5$ mm). On the other hand, sample A had more uniform size distribution: 32% large, 28% medium-sized and 40% small fractions. The geometric mean diameter ranged from 1·98 to 2·53 mm, while the corresponding surface area took in between 12·3 and 20·1 mm^2. The sphericity of achene was among 0·42 and 0·54. Besides, the angle of repose was from 28·6° to 30·2°. These results indicate that the flat shape of seeds makes it difficult to roll on surface and facilitates sliding.

In contrast, cultivated sunflower seeds (*H. annuus*) exhibited higher length, width, and thickness, the reported means being 9·52, 5·12 and 3·27 mm, respectively (Gupta & Das, 1997). About 80% of cultivated sunflower seeds had lengths ranging from 8 to 10 mm; around 11% greater than 10 mm; and the rest, less than 8 mm. The mean equivalent diameter was 5·39 mm and the sphericity 0·57 (Gupta & Das, 1997).

Figure 1 presents a scanning electron microphotography carried out at a ×24 magnification. The surface of the achenes has abundant hairs with most being straight and double, united for most of their length (*Fig. 2*). The achenes are more abundant and significantly larger (approximately 400–600 μm length by 10 μm width) than in *H. annuus*. This characteristic is a feature in wild species and serves as a defence mechanism against diseases (Seiler, 1997).

A sunflower achene is made up of a true seed called the kernel, and a lingo-cellulosic pericarp enclosing the seed, usually called the hull. The pericarp structure of cultivated sunflower is regarded as complex, which is constituted by different tissues (Seiler, 1997). The hull is made up of

(a) the outer layer, called the epidermis, and formed by rectangular cells covered with a thin cuticle in its outer walls;
(b) the hypodermis, comprising four or six layers of cells arranged in radial rows;
(c) a phytomelanin layer, present in some cultivars and described as carboniferous, resinous and amorphous;

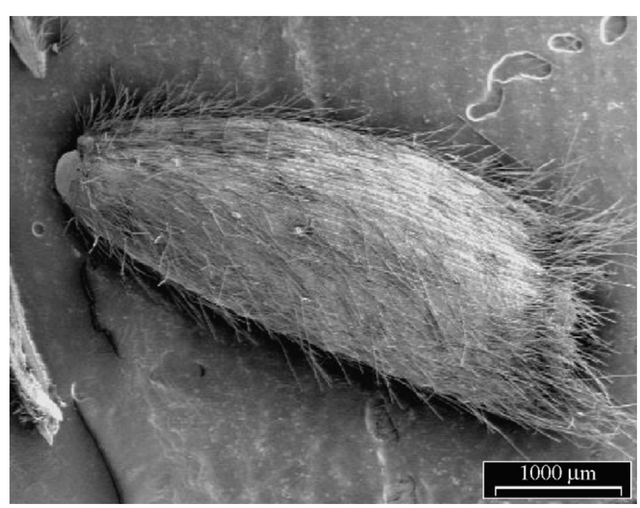

Fig. 1. Helianthus petiolaris achene microphotograph (×24)

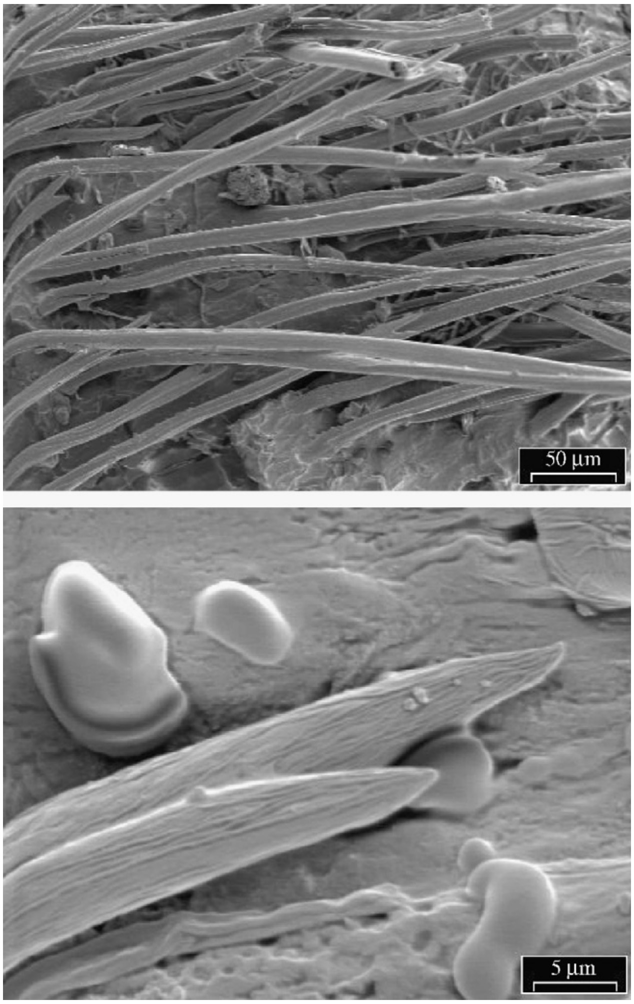

Fig. 2. Scanning electron micrographs of outer surface (× 320) and hairs (× 3200) of Helianthus petiolaris

(d) the middle layer, made up of sharp-cornered polygonal cells, which are developed into a secondary thickening of the walls to become sclereids; and
(e) the inner epidermis, composed of parenchyma cells, which are thin-walled and loosely packed.

As to the kernel, it consists of

(a) a seed coat made up of three layers of parenchyma cells;
(b) the endosperm with a single layer of aleurone cells; and
(c) the embryo, which is made up mostly of cotyledons.

Figure 3 shows the appearance of the cross-section of wild sunflower pericarp, which was magnified at × 540. The epidermal cells with a thin cover called cuticle and the trichome basal cells that project above the surrounding epidermal cells can be observed. The pericarp structure also presented a disorganised and lignificated fibre layer.

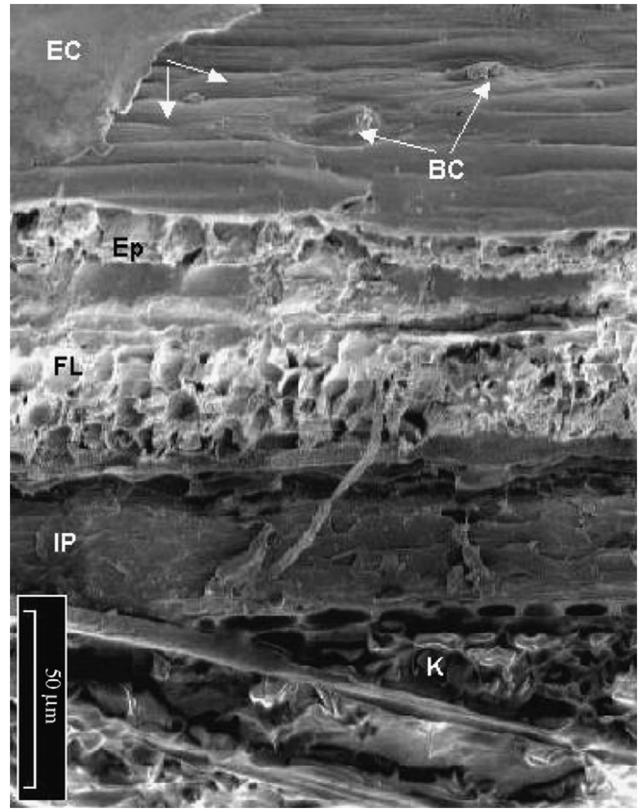

Fig. 3. Pericarp of Helianthus petiolaris (540 ×). EC, epithelial cell; BC, basal cell; Ep, epidermis; FL, fibre layer; IP, inner parenchyma; K, kernel

In a previous paper, we reported amounts of fibre that had between 24·2% and 39·4% dry matter, the contents being higher than those from cultivated sunflower (21–30%), particularly cellulose and lignin (Perez *et al.*, 2004). In addition, there are air cavities between the inner parenchyma and the cotyledon. These air cavities affect the achene true density and gives significant differences between true seed density (399 kg/m^3) and true meal density (1076 kg/m^3). It was difficult to hand-separate seed into hull and kernel because of the small size of the achene and because the hull was tightly fitting around the kernel. For this reason, the mean hull thickness and percentage were evaluated by microphotography analysis and resulted in 0·07 mm and 21%, respectively. These results are in agreement with those for oilseed sunflower hulls, which comprise 20–28% of the total achene weight.

4. Conclusions

The following conclusions are drawn from this investigation on wild sunflower seeds.

(1) The average length, width, thickness, and mass of the seed were 4·5, 2·02, 1·2 mm, and 6·8 g/1000 seeds,

respectively, which is significantly lower than those corresponding to commercial sunflower seeds.

(2) The seed mean values of equivalent diameter, surface area, and sphericity were 2·25 mm, 16·2 mm^2 and 0·48 mm, respectively.

(3) The average angle of repose was 29·4°, showing that the flat shape of the seeds facilitates sliding.

(4) The averaged bulk and true densities were 350 and 399 kg/m^3, and this characteristic may be used in designing a cleaning process for the seeds.

(5) The oil content ranged between 27% and 30% (wb), representing 60–70% of the amount that is industrially obtained from new cultivated sunflower seed varieties.

(6) The mean hull thickness was 0·07 and the hull percentage was 21%, slightly lower than in cultivated sunflower.

(7) The surface of the achenes has abundant straight hairs which can serve as a defence mechanism against diseases.

(8) The microphotographic study showed a pericarp structure with a disorganised and lignificated fibre layer, and air cavities between the inner parenchyma and the cotyledon.

In brief, this report provides physical properties and morphological data about *H. petiolaris* seeds, thus expanding the knowledge about this species and providing useful data for its industrial processing.

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