Australian Lupin Bean physical structure and characteristics

The Australian Lupin Bean is the seed harvested from the Australian sweet lupin (*Lupinus angustifolius*). The beans typically weigh 140-150mg have a bulk density of approximately 78 kg/hectolitre. (source Department of Agriculture and Food - www.agric.wa.gov.au).

Lupins are often referred to as a 'grain legume' and sometimes as a 'pulse'. However, the word pulse comes from the Latin word 'puls' which means 'potage' or thick soup. As lupins contain almost no starch (responsible for soup thickening) they are technically not a pulse. The lupin seed or 'grain' shares some structural similarities to the pulses and soybean being a dicot with two large cotyledons in the seed. Again, it is very distinguishable from the soybean in that it contains much less lipid (oil) and much more dietary fibre.

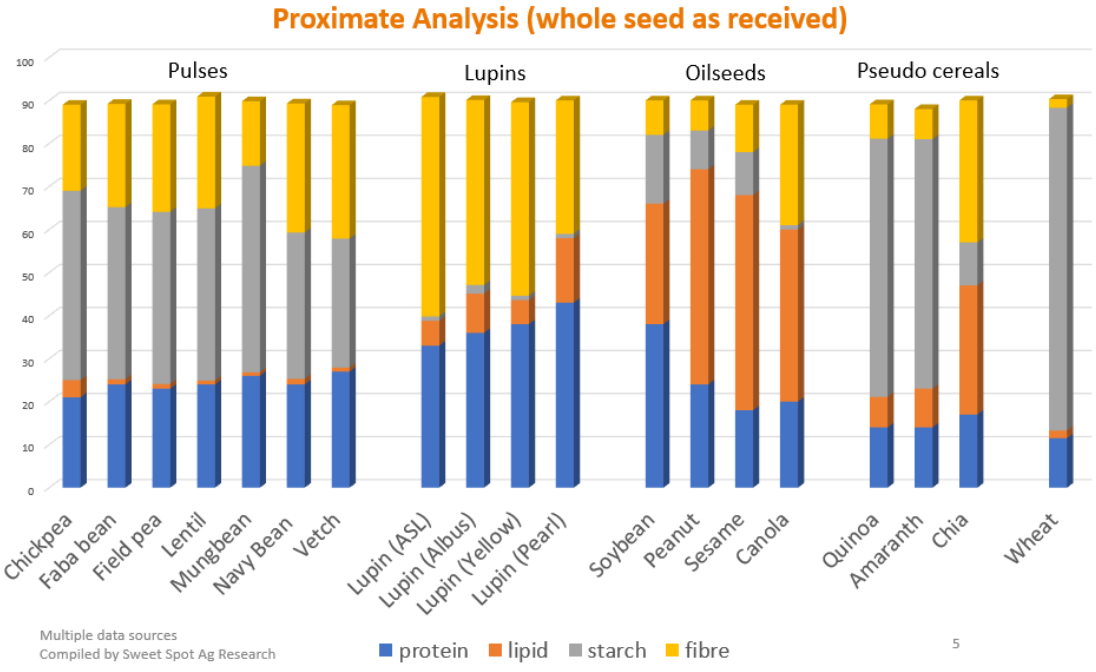

Figure 1. The unique seed composition of lupins compared to other legumes and grains.

The Australian sweet lupin produces seeds within a long narrow pod (Figure 2). The seed is harvested when the pods are mature and dry (when the moisture content of the seed has typically dropped to 9 -11 %). At this stage the seed is stable in storage and naturally protected from insect and microbial attack by a robust seed coat.

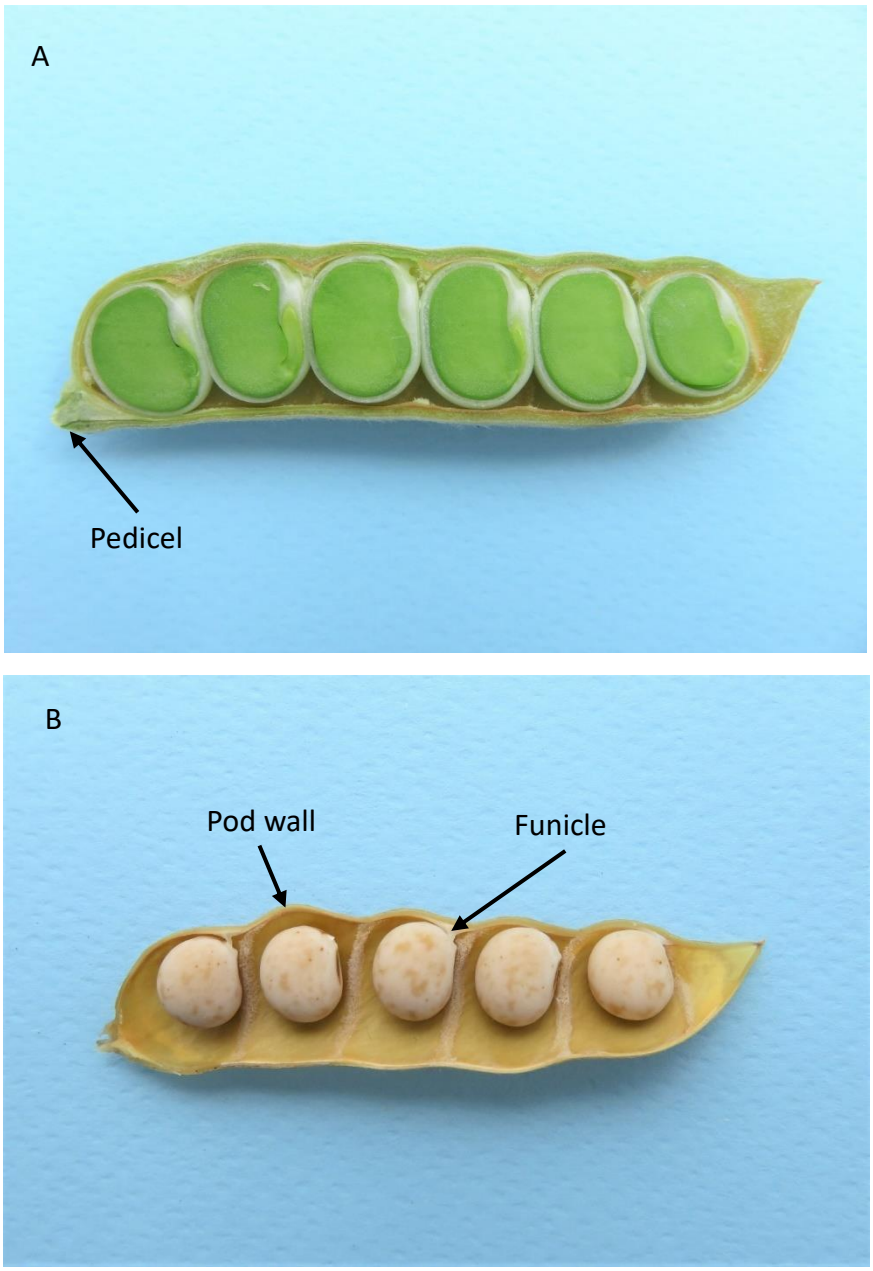

Figure 2. Australian sweet lupin pod

A. Section through a pod and seeds close to physiological maturity
B. Opened pod with seeds close to harvest maturity

The Australian Lupin Bean is similar in structure to other legume seeds in that it comprises a seed coat, enclosing two cotyledons, an embryonic axis made up of radicle (the embryonic root within the radicle pocket), hypocotyl (stem region below cotyledons), epicotyl and plumule (the immature shoot and preliminary leaf tissue). The hilum (scar region where seed was attached to the pod wall by the funiculus) and the micropyle (point of entry where pollen fertilised the ovule) remain visible on the mature seed. (Figure 3).

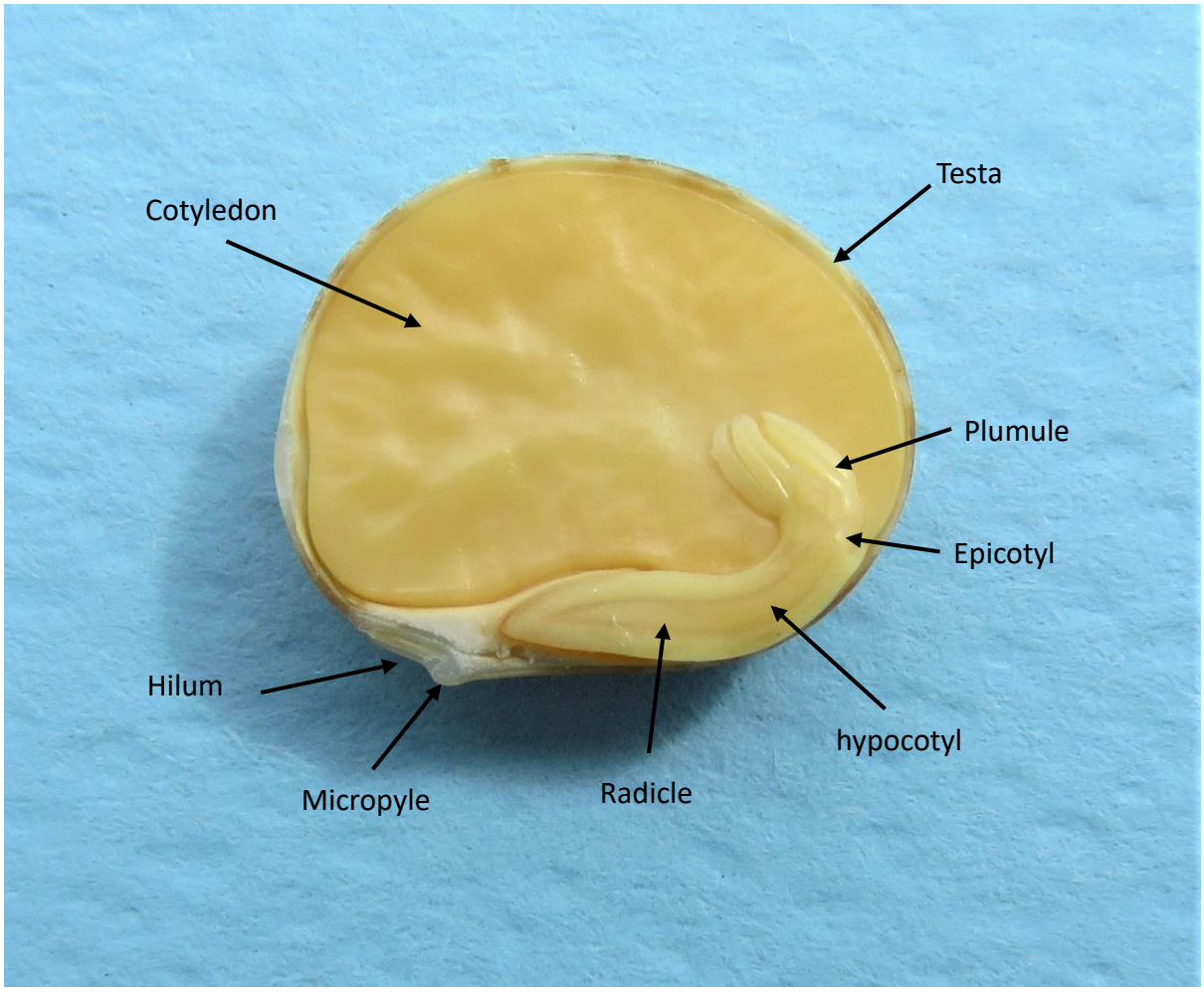

Figure 3. Section through an Australian Lupin Bean with one cotyledon removed to expose the embryo.

Lupins and some other legumes have an essentially depleted endosperm. During seed development the endosperm supplies nutrients to the developing cotyledons, which in lupin and many other legumes (eg. peas, peanut, phaseolus beans), completely fill the seed by maturity. The endosperm is completely consumed by the developing embryo - such seeds are called non-albuminous or ex-albuminous seeds.

The Hull

The Australian Lupin Bean "hull" or seed coat (botanically the testa), comprises about 25% of the seed weight, with a thickness of approximately 200 µm in Australian sweet lupin varieties (Clements *et al.*, 2005; Clements *et al.*, 2004). This is a significantly higher hull proportion than in domesticated pulse species (eg. 9% in field pea, 8% in lentil and 14% in faba bean) and compared to soybean (7%) (Güzel and Sayar, 2012; Lush and Evans, 1980; Ali-Khan, 1993).

Hulls are maternal tissue (ie. the diploid genotype belonging to the mother plant), in contrast to the embryo and cotyledons which are the embryonic stage of the young sporophyte (genetically diploid) resulting from fertilisation by a pollen tube. During seed formation, as the embryo and cotyledons grow larger, nutrient supply from the endosperm progressively depleted and the hull plays an increasing role as nutrients are released directly from the seed coat tissues.

The Australian Lupin Bean hull is made up of 90% cell walls. It is constructed of three layers: the palisade cell (macrosclereids) layer (consisting of two distinct layers – palisade 1, palisade 2 or sub-palisade); a thick-walled hourglass cell (osteosclereids) layer, and the parenchymal cell layer (Clements *et al.*, 2005; Zhong *et al.*, 2018; Tiwari and Singh, 2012) (Figure 4). These cell walls are composed of structural polysaccharides, predominantly cellulose and arabinoxylan hemicelluloses and pectin. The lignin content is low (1.5%) with only a trace of oligosaccharides and monosaccharides (Evans *et al.*, 1993).

Australian sweet lupin varieties have varying seed coat patterns from white with brown hilum mark (eg. older variety Danja) to light brown sparse mottled (eg. Coromup, PBA Jurien), to highly mottled brown (eg. Mandelup, PBA Barlock). Flavonoids (including anthocyanins, and proanthocyanidins) have been reported to be the main contributor to legume seed coat colour (MoÏSe *et al.*, 2005).

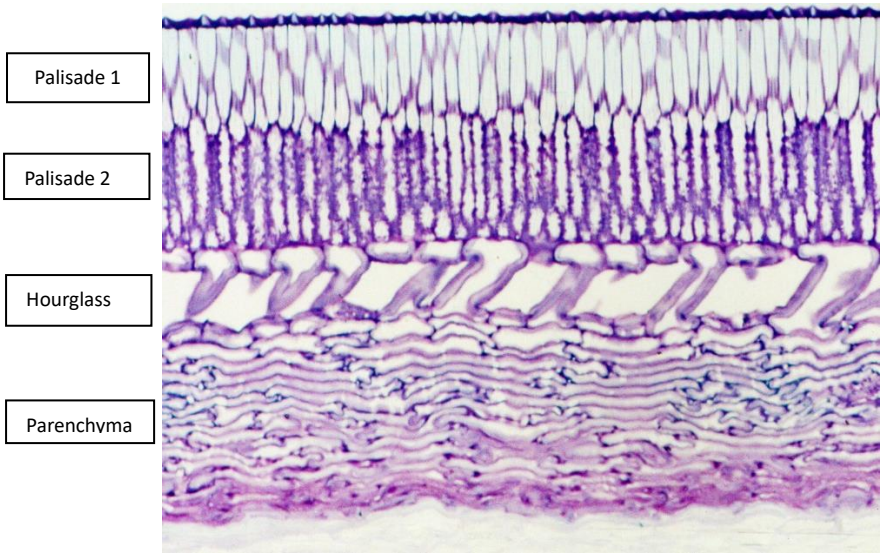

Figure 4. Cell layers within the seed coat of the Australian Lupin Bean

The kernel

The dehulled seed component is referred to as the "kernel" (botanically being the cotyledons and the embryo excluding the radicle portion that adheres to the testa).

With approximately 40 % protein, Australian Lupin Bean kernels have the highest protein level of any commonly consumed legume. The protein bodies (Figure 5) in cotyledon cells are reported to be 5 to 25 µm in size, consist of approximately 73 % protein dry solids and are distributed throughout the cytosol (Pelgrom et al., 2014). The majority of these protein bodies are composed of α and β conglutin. However, the lupin specific protein γ conglutin, which is physiologically active protein with insulin mimetic properties is present in smaller bodies located in the cell walls and the vicinity of the plasma membrane (Duranti *et al*., 1994).

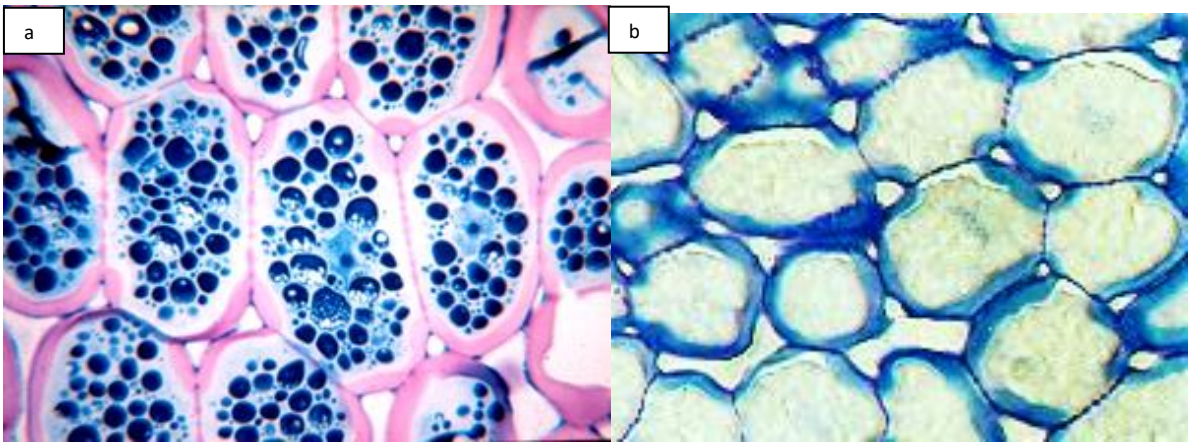

Figure 5. Periodic acid schiff (a) and toluidine blue (b) stained sections of Australian Lupin Bean cotyledon showing thickened cell walls of the mesophyll cells [pink in (a), blue in (b)] and protein bodies within these cells [blue in (a), faint translucent in (b)].

Unlike the pulses, the Australian Lupin Bean kernel is almost devoid of starch and rich in dietary fibre. Polymers of galactose, arabinose and uronic acids are the major constituents of the thick cotyledon cell walls, which together with some oligosaccharides providing an excellent source of dietary fibre making 30% of the kernel (Wrigley, 2003; Johnson *et al*., 2017; Mazumder *et al*., 2021).

The Australian Lupin Bean kernel contain approximately 8% oil. Oil bodies occur mainly in the cotyledons, scattered throughout the cytosol, and less frequently in the embryo (Borek *et al*., 2013).

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