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Effect of Genotype and Pretreatment of Field Peas (*Pisum sativum*) on their Dehulling and Cooking Quality

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Abstract: Field peas (*Pisum sativum*), an important pulse crop in Australia, are consumed as human food either as whole seeds or as splits after decortication. The yield of splits is an important economic factor for processors and the cooking quality is important for consumers. Effects of genotype, other physical characteristics and pretreatment in various solutions on both dehulling and cooking quality were studied for 23 known genotypes and are market sample of unknown genotype. Large variations were found for most characteristics. Seed size was positively correlated with yield of splits while husk content and broken seeds were negatively correlated with yield. Preconditioning seeds in salt solutions improved yield of splits. Variation in cooking quality among genotypes was reduced following splitting and cooking time was reduced by decortication and splitting and by presoaking in salt solutions (10 or 20 g kg^{-1}), particularly with sodium tripolyphosphate. Loss of seed material into cooking water was correlated with cooking time. No characteristic was found that could be used to predict cooking time. © 1998 SCI.

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Key words: field peas; dehulling; *Pisum sativum*; conditioning; splits; yield; cooking quality

INTRODUCTION

Pulses are important sources of protein, complex carbohydrates, vitamins and minerals in the daily diets of many millions of people, particularly in the developing countries. Among the world's pulses, dry peas (also called field peas, *Pisum sativum*) are second to dry beans in production and consumption (FAO 1993) and the second most important pulse crop in Australia, next only to lupins in area and production. Field peas are consumed after cooking both in the form of whole seed and decorticated splits in various types of food. It is believed that at least half of the dry peas harvested in Australia are dehulled before being consumed. Dehulling and splitting are processes which remove the seed coat or hull (decortication step) and then split the cotyledon into its two halves, called 'splits'. In this paper, the term 'dehulling' refers to the combined steps of seedcoat removal and splitting, reflecting commercial practice in Australia.

Quality attributes of field peas for human consumption include dehulling efficiency (important for processors) and cooking quality (for consumers). The chemical composition and nutritive value of dry pea genotypes have been shown to have large differences (Mosse *et al* 1987; Gueguen and Barbot 1988). However, there is little information on any differences among genotypes in terms of their dehulling efficiency or cooking quality. Although the efficiency of dehulling (yield of 'splits') will depend on the method and machinery used, several factors such as environment, agronomic practices, grain characteristics and pretreatments (processes to loosen the hulls before dehulling) are known to influence the dehulling process in some pulses (Ramakrishnaiah and Kurien 1983; Reichert *et al* 1984; Singh 1995).

Laboratory studies on dehulling efficiency of pulses have used many devices such as the Tangential Abrasive Dehulling Device (Reichert *et al* 1986; Singh *et al* 1992a) which measures yield of seed coat. Swamy *et al* (1991) and Sachan *et al* (1993) used a Satake laboratory mill in studies on Red Gram and soybean, respectively.

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Early trials in this laboratory found that the Satake device could be used for both decortication and splitting of field peas in a very short time. Preconditioning of the seeds before processing to make decortication easier has been accepted for many pulses (Swamy *et al* 1991; Sachan *et al* 1993) but little appears to have been reported on preconditioning of field peas. Therefore, the present work was undertaken to study the effects of physical grain characteristics and preconditioning on the dehulling efficiency of Australian field peas.

Long cooking times of pulses is a major constraint to wider use of pulses and can reduce their nutritive value causing losses of methionine (Shermer and Perkins 1975) and reduction in the nutritive value of their proteins (Chandreshaker *et al* 1981). The cooking quality of pulses has been the subject of many studies (Muller 1967; Rockland *et al* 1979; Parades-Lopez *et al* 1991; Singh *et al* 1993). To date, nothing has been published about the cooking quality of Australian field peas. Factors considered important in cooking quality such as dehulling, genotype and presoaking before cooking were therefore studied.

MATERIALS AND METHODS

Materials

Field peas grown in the 1994–1995 season on the experimental farm at the Victorian Institute for Dryland Agriculture, Horsham were supplied by the pulse breeder. Twenty three known genotypes were selected covering a wide range of morphological attributes (dun, blue, white, wrinkled and mottled types, covering a wide range of seed size) for this study. All samples were tested 4 months after harvest. In addition, a 'market sample' supplied by a commercial splitter, was used as a reference. Seeds were cleaned by aspiration and sieving on a 5·0 mm screen to remove infected, damaged and immature seeds.

Preconditioning treatments

For dehulling

Using a blue type pea, highly regarded commercially for good dehulling qualities, various treatments were investigated: soaking in water, solutions of sodium bicarbonate (10 g kg^{-1}), sodium chloride (10 g kg^{-1}), smearing with vegetable oil (10 g kg^{-1}) and preheating. Seed (50 g) was soaked in 100 ml of water or salt solution at room temperature (20°C) for 10 min. Excess liquid was removed with tissue paper and seeds dried for 30 min in an oven at 70°C. For edible oil treatment, 50 g seed was thoroughly smeared with 0·5 g of refined peanut oil then dried in the oven for 30 min at 70°C. The preheating treatment consisted of heating for 30 min in an oven at 70°C. The Control sample had none of these treatments and when the 23 known genotypes were tested, no pretreatment was used. All tests were performed in duplicate.

For cooking

Whole seeds or splits were soaked at 20°C for 1 H in water and solutions of sodium chloride, sodium carbonate and sodium tripolyphosphate at levels of 10 g kg^{-1} and 20 g kg^{-1} and in a mixed-salts solution containing 15 g kg^{-1} of equal portions of sodium chloride, sodium bicarbonate and sodium tripolyphosphate. After soaking, excess liquid was discarded and the sample used for determination of cooking time. When the cooking time for 23 genotypes was compared, the seeds were not presoaked.

Dehulling conditions

The Satake Grain Testing Mill TM05 (Satake Engineering Co Ltd, Japan) fitted with an abrasive wheel mesh 40 with a clearance of 13·5 mm from the screen and operated at 750 rpm was used. These conditions were suitable for processing field peas with 100-seed mass in the range 13–30 g. Samples (30 g) of all the above treatments were dehulled in the Satake mill for 10 s. All the material from the treatment was recovered and five fractions were prepared by sieving to remove brokens and powder followed by aspiration of husks from the splits. The five fractions were:

- Undehulled seed (manually removed)
- Splits retained on 1·70 mm sieve
- Husks retained on 1·70 mm sieve and removed by aspiration
- Brokens retained on 0·85 mm sieve
- Powder passed through 0·85 mm sieve

Dehulling efficiency (an estimate of the efficiency of producing the major product, splits) was calculated as follows:

$$\text{Dehulling efficiency (\%)} = \frac{(W_1 - (W_2 + H + B + P)) \times 100}{W_1}$$

$$\text{\% Undehulled} = \frac{W_2 \times 100}{W_1}$$

$$\text{\% Husk} = \frac{H \times 100}{(W_1 \times W_2)}$$

$$\text{\% Brokens} = \frac{B \times 100}{(W_1 - W_2)}$$

$$\text{\% Powder} = \frac{P \times 100}{(W_1 - W_2)}$$

where W_1 is the initial weight of sample, W_2 is the weight of undehulled seed, H is the weight of husks, B is the weight of brokens and P is the weight of powder.

Note: the calculations for % husk, % brokens and % powder are made relative to the seed that has been dehulled, thus the denominator is $(W_1 - W_2)$.

Husk content

This was a measure of the husk content by a manual method of husk removal: a sample (10 g) of seed was soaked in 50 ml water at room temperature (20°C) overnight. Water was removed and the husk manually removed using forceps. Husks and cotyledons were dried separately in an oven at 70°C overnight and allowed to cool at room temperature for 1 h. Dried and cooled husk and cotyledon components were weighed and husk content was calculated.

Cooking time

A standard laboratory hotplate supplied by Bartelt Instruments, Melbourne, Victoria (460 mm × 260 mm) was used and uniform and constant temperature maintained during boiling. Approximately 200 ml of deionised water was brought to boiling in a 250 ml beaker and 30 g of the soaked sample (whole or split seeds) added. Boiling was continued, water added as necessary to maintain volume and samples (4–5 seeds or splits) were withdrawn using a spatula at 1 min intervals (splits) or 2 min intervals (whole seeds) and tested for softness by pressing between finger and thumb as described by Singh *et al* (1984). The time from addition of seeds to achieve the desirable softness was recorded as the cooking time.

Water absorption

One hundred seeds or splits were weighed, transferred to a 250 ml beaker and 100 ml of water or salt solution added. The beakers were allowed to stand at 20°C for 16 h. After soaking, excess water or salt solution was discarded, traces of water removed by blotting with tissue paper and the seeds reweighed. Water absorption (g kg^{-1} water or salt solution absorbed) was calculated using the following formula:

$$\text{Water absorption} = \frac{(W_2 - W_1) \times 100}{W_1}$$

where W_1 is the initial weight and W_2 is the weight after absorption.

Hard seed coatedness

This is a measure of the proportion of seeds that do not swell after overnight soaking. The number of seeds not swelling in the water absorption test from the 100 tested is recorded.

Cooking losses

This test was applied to samples in the soaking solution experiment. After cooking, cooked seeds were removed from the cooking water and dried in an air oven at 70°C overnight and re-weighed. The % cooking loss was calculated from the loss in weight of dried seeds (solids lost into the cooking water) after allowing for initial moisture content.

Solids dispersion

Preliminary trials with samples having a wide range of cooking times found that solids lost in cooking water was related to the time the particular sample was cooked. To standardise the method across all genotypes with a large range in cooking times, the 'cooking loss' method was modified by cooking a 10 g sample in water or salt solution for times less than the shortest cooking time for all genotypes, namely 60 min (whole seed) and 19 min (splits). The percentage of solids dispersed was calculated in the same way as for the 'cooking loss' test.

Moisture content

Ground seeds were dried in a convection oven set at 110°C for 16 h.

One hundred grain weight

After cleaning and grading, a lot of 100 seeds was randomly selected and weighed.

Flotation value

This was measured using the method of Singh *et al* (1992b): at ambient temperature, 100 seeds were dropped into 150 ml of a solution of sodium nitrate (1·5 g kg^{-1}) and stirred thoroughly. After 2 min the number of seeds floating on the surface was counted and flotation % calculated.

Grain volume

A 10 g sample was dropped into 20 ml water at 20°C in a 50 ml measuring cylinder. The final volume was read and the increase in volume recorded. Results were expressed as grain volume (ml) per 100 g of sample and as grain volume (ml) per 100 seeds.

Precision of the Satake machine

This was done on 10 replicates using three pea samples: a white type, a dun type and a blue type. The variance among the replicates was calculated.

RESULTS AND DISCUSSION

Dehulling quality

Statistical analysis of the Precision test on the Satake machine (Table 1) gave a coefficient of variation ranging from 0·59 to 1·08% in yield of splits. This was considered a satisfactory result. Precision for other minor components was not as good and this was believed due to variable sieving properties of brokens and powder. The correlation found between husk content by the Satake and by the manual method was statistically significant (Table 2) although values for the two methods were often different. This is believed due to much of the husk from varieties with soft husk being ground to small particles in the Satake machine and recorded with powder rather than with husk.

Results of the effects of a number of pretreatments on dehulling quality are shown in Table 3. Compared with the Control (no pretreatment), soaking in water or salt solutions followed by preheating marginally increased dehulling efficiency while preheating alone had no effect. The effect was more pronounced when sodium bicarbonate solution was used. There were some reductions in husk recovery as a result of pretreatments while the amount of powder tended to increase. This suggests the husk was made more fragile by pretreatment. Treatment with oil, commonly used on pigeonpea with hulls that are difficult to remove (Singh 1995) produced an improvement similar to that of water treatment. Srivas-

TABLE 1
Precision[a] of the laboratory dehulling process using the Satake mill

Variety Type		*Dehulled fractions* (%)				
		Undehulled	*Splits*	*Husk*	*Brokens*	*Powder*
White Type	Maximum	0·0	88·2	7·7	2·7	3·5
	Minimum	0·0	86·2	6·9	2·0	2·3
	Mean	0·0	87·3	7·3	2·5	3·0
	SD	0·0	0·54	0·23	0·21	0·34
	CV%	0·0	0·62	3·15	8·40	11·30
Dun Type	Maximum	0·0	81·9	11·9	4·5	4·2
	Minimum	0·0	80·3	10·0	3·6	3·4
	Mean	0·0	81·3	10·9	4·1	3·7
	SD	0·0	0·48	0·54	0·28	0·23
	CV%	0·0	0·59	4·95	6·83	6·22
Blue Type	Maximum	0·0	84·0	10·5	3·5	3·6
	Minimum	0·0	81·5	8·6	2·8	2·9
	Mean	0·0	82·6	9·6	3·2	3·3
	SD	0·0	0·89	0·54	0·23	0·24
	CV%	0·0	1·08	5·62	7·19	7·27

[a] Based on 10 replicates.

TABLE 2
Correlation of dehulling and other physical characteristics of field peas

Characteristics	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
(1) Seed size	1·000									
(2) Husk a[a]	−0·272	1·000								
(3) Moisture	0·598**	−0·282	1·000							
(4) Floatation	0·687**	0·118	0·417*	1·000						
(5) Grain volume (ml per 100 g)	0·434*	0·194	0·297	0·687**	1·000					
(6) Grain volume (ml per 100 grain)	0·984**	−0·19	0·534*	0·712**	0·480*	1·000				
(7) Dehulling efficiency	0·408*	−0·776**	0·271	−0·137	−0·048	0·368	1·000			
(8) Husk b[b]	−0·365	0·602**	−0·235	0·055	0·213	−0·329	−0·709**	1·000		
(9) Brokens	0·131	0·486*	0·124	0·339	0·162	0·173	−0·487*	0·062	1·000	
(10) Powder	0·652**	0·158	0·353	0·531*	0·215	0·676**	−0·126	−0·269	0·627**	1·000

[a] Husk a was manually dehulled.
[b] Husk b was dehulled by Satake mill.
* Significant at 5% level; ** significant at 1% level

TABLE 3
Effect of preconditioning treatments on dehulling quality of a blue type field pea (CP 128952)

Treatment	*Dehulled fractions* (%)				
	Undehulled	*Splits*	*Husk*	*Brokens*	*Powder*
Control	0·00	81·1	12·9	3·6	2·3
Water	0·00	81·9	11·8	3·7	2·5
Sodium chloride	0·00	82·3	11·5	3·2	2·8
Sodium bicarbonate	0·00	82·4	11·6	3·2	2·8
Edible oil	0·00	81·7	12·2	2·9	3·1
Preheating	0·00	81·0	12·2	3·2	3·4

tava *et al* (1988) reported that dehulling efficiency was improved when sodium bicarbonate was used as a soaking solution for preconditioning pigeonpeas. Erskine *et al* (1991) also found that the best dehulling efficiency of lentils was obtained after soaking in water of 1 min followed by air drying. Swamy *et al* (1991) reported that husk in pulses is rich in non-starchy polysaccharides which are solubilised and that husk becomes softened after soaking in water or salt solutions.

Further work would be required to determine to what extent if any, retention of sodium in the cotyledons, following soaking in one of the sodium salts, presents a potential nutritional disadvantage. Further laboratory trials are planned using a wider range of cultivars that may provide more convincing data. Industrial scale trials are recommended before pretreatment could be considered a commercial advantage.

A large variability in dehulling quality existed among the 23 genotypes and market sample studied (Table 4), reflected by variation of other grain characteristics. Seed size is generally considered to be the major factor affecting dehulling of pulses (Ehiwe and Reichert 1987; Singh *et al* 1992b). It is a varietal characteristic which can be strongly influenced by growing seasons and locations (Erskine *et al* 1985; Williams and Singh 1987). One hundred-weight of field pea genotypes in this study ranged between 13·0 and 30·0 g, a large variation (Table 4). Husk content obtained by a manual method ranged from 8·1 to 13·0% and a similar range was found using the Satake mill. Moisture content ranged from 59 to 107 g kg^{-1}, there was almost a five-fold variation in flotation values (seed density measure) and grain volume (per seed) showed a large range (Table 4).

The yield of splits is the most important factor in splitting efficiency. Dehulling efficiency is often calculated commercially using the uncleaned seed as the base, when a lower yield figure will be obtained. This study calculated yield from a base of cleaned seeds where it ranged from 71·1% (WT 12077, a dun genotype) to 85·7% (CP 128940, a blue genotype). The average yield for the 23 known genotypes and market sample, 79·3%, is slightly higher than that reported for

TABLE 4
Dehulling quality and grain physical characteristics of field pea genotypes

Genotype	*Grain colour*	*Weight of 100 seeds* (*g*)	*Husk a*[a] (%)	*Moisture* (*g* kg^{-1})	*Flotation* (%)	*Grain volume* (*ml*)		*Dehulling efficiency* (%)	*Dehulling fraction* (%)			*Husk b*[b]
						(*100 g*)	(*100 grains*)		*Undehulled*	*Brokens*	*Powder*	
CP 129152	White	15·3	8·4	70	38·5	70·8	11·3	79·06	4·92	3·00	2·50	11·40
WA 574	White	13·1	8·6	70	21·0	75·2	9·8	73·35	14·07	3·56	2·44	8·63
WA 719	White	14·6	8·8	65	18·5	60·3	10·4	71·29	12·31	3·83	3·60	11·27
SA 0239	White	30·1	8·8	89	83·0	81·7	22·5	82·25	2·13	2·75	3·97	9·24
SA 0244	White	28·4	8·5	79	91·0	84·5	23·0	84·33	0·00	2·80	3·83	9·05
PI 212916	White	18·2	9·5	107	45·0	68·0	12·6	82·64	2·30	2·45	2·28	10·67
Ramio	White	20·4	10·2	73	29·5	76·5	16·5	82·42	0·60	3·07	3·94	10·08
CP 128940	Blue	20·6	8·7	67	47·5	76·0	16·8	85·72	0·00	2·51	2·35	9·42
CP 128952	Blue	17·0	9·1	67	36·0	72·5	11·0	81·09	1·43	3·47	3·17	11·09
CP 129155	Blue	14·4	8·8	65	34·5	70·5	10·8	79·84	4·56	2·93	2·61	10·81
Multipod	Blue	21·7	9·0	70	73·5	78·4	17·0	81·95	1·66	2·50	2·36	11·81
WA 639	Dun	13·0	12·4	59	61·5	83·0	11·3	81·72	1·59	3·65	2·68	10·63
PI 180702	Dun	14·9	13·0	63	20·5	64·1	12·0	80·41	3·16	3·64	3·09	10·25
WT 12077	Dun	13·5	14·9	67	38·0	79·0	11·0	71·16	10·10	3·84	3·18	13·82
PI 195024	Dun	21·2	10·2	69	76·0	78·9	16·8	81·19	2·09	3·93	3·96	9·18
PS 0708	Dun	25·8	11·3	81	100·0	89·4	21·5	71·65	11·00	4·29	3·66	11·54
Dundale	Dun	20·3	10·8	66	62·5	52·0	16·0	76·41	7·49	4·28	4·14	8·99
Market sample	Dun	16·6	12·6	72	60·0	81·0	12·6	75·03	7·60	3·41	3·05	12·32
CPI 091411	Mottled brown	13·0	12·6	61	80·5	81·2	9·3	73·77	10·60	3·24	2·87	11·37
Hero	Mottled brown	16·5	8·1	97	63·0	77·0	12·3	80·25	3·86	3·15	3·12	10·25
WT 12078	Mottled purple	13·8	12·4	75	74·0	80·2	10·9	79·02	0·00	5·19	3·59	12·20
WA 571	Mottled purple	23·7	12·1	78	99·0	88·6	19·5	79·33	1·00	3·56	3·12	13·19
Zelka	Wrinkled green	30·0	9·4	98	88·0	83·8	24·4	82·20	0·00	4·45	4·52	8·83
COB 190175	Wrinkled orange	29·7	10·9	102	93·0	86·4	22·8	84·08	0·60	5·17	1·17	9·07

[a] Husk a was determined manually.
[b] Husk b was determined by Satake mill.

commercial mills (about 75% split yield). The theoretical maximum yield is about 90% as the husk content by the manual method ($Husk_a$) was about 10% (Table 4). The difference between theoretical and actual efficiency by both laboratory and commercial processes indicates there is scope for further improvement of these mechanical processes, for example by reducing brokens and powder. Alternatively, genotypes may be developed that resist break up into brokens and powder during dehulling.

Table 2 shows the correlation coefficients among the seed characteristics and dehulling efficiency. As expected, dehulling efficiency was positively though weakly correlated with seed size and negatively correlated with yield of both brokens and husk contents. Grain density, whether measured by grain volume per 100 g, grain volume per 100 grains or indirectly by flotation, was not correlated with dehulling efficiency. Singh *et al* (1992a) also found no significant correlations between splits yield, swelling capacity and flotation values for pigeonpea.

When the 23 genotypes were grouped into main morphological types (blue, white, dun, wrinkled, mottled) the yield of brokens and powder were clearly lower in the blue types, followed by the white types. Worst were the wrinkled types while dun types, most commonly used for splitting in Australia, were intermediate. This observation will be further studied using a larger number of samples.

Cooking quality

As with dehulling quality, a large variation was found in cooking quality among the 23 known genotypes. In Table 5, water absorption ranged from 449 g kg^{-1} to 1087 g kg^{-1} for whole seeds and from 880 g kg^{-1} to 1050 g kg^{-1} for splits, indicating that dehulling reduces the variation, much of which must come from the nature of the seed coats. Except for genotype WT 12078, cooking time of splits ranged between 19·0 and 45·0 min, while for the corresponding whole seeds the range was from 79·0 to 140 min. Decortication therefore reduced both the overall cooking time and the variability among genotypes. It is well documented that cooking time is a heritable characteristic for pulses (Williams and Singh 1987). These data will be useful for breeders to select genotypes with shorter cooking times. The market sample, a dun type, was typical of other dun varieties in most properties. Hard seed coat was highly variable (from 0 to 43% of seeds failed to hydrate) and the large number of genotypes with 20% or more of seeds not hydrating is a cause for concern. Solids lost into the cooking water were higher for splits (mean 190 g kg^{-1}) than for whole seeds (mean 116 g kg^{-1}), indicating retention of solubles within the seed coat during cooking of whole seeds, even over a much longer cooking time.

When the genotypes were grouped into the main classes of white, blue, dun, mottled and wrinkled,

TABLE 5
Variability in cooking quality parameters of whole seed and splits of field peas

Genotype	*Seed colour*	*Weight of 100 seeds (g)*	*Moisture (g kg^{-1})*	*Hard seed coat (%)*	*Whole seed water absorption (g kg^{-1})*	*Whole seed cooking time (min)*	*Whole seed solid dispersion (g kg^{-1})*	*Splits water absorption (g kg^{-1})*	*Splits cooking time (min)*	*Splits solid dispersion (g kg^{-1})*
WA 574	White	13·1	70	0	1027	90	157	950	29	201
CP 129152	White	15·3	70	3	865	82	151	890	22	231
SA 0244	White	28·4	79	3	1004	140	82	1000	28	209
PI 212916	White	18·2	107	30	528	105	82	940	28	192
Ramio	White	20·4	73	2	940	137	93	880	30	193
WA 719	White	14·6	65	0	990	85	130	1010	19	219
SA 0239	White	30·1	89	7	757	124	92	900	21	217
CP 128940	Blue	20·6	67	0	925	109	84	800	24	178
CP 128952	Blue	17·0	67	0	952	86	105	950	24	186
CP 129155	Blue	14·4	65	10	929	82	142	960	23	205
Multipod	Blue	21·7	70	1	954	86	144	950	21	229
PI 180702	Dun	14·9	63	11	747	109	160	850	45	199
WA 639	Dun	13·0	59	21	859	79	113	1030	19	223
WT 12077	Dun	13·5	67	3	916	132	116	980	30	185
PI 195024	Dun	21·2	69	25	449	83	113	1050	20	204
PS 0708	Dun	25·8	81	1	1096	93	158	1000	22	216
Dundale	Dun	20·3	66	12	763	93	117	995	25	235
Market sample	Dun	16·6	72	6	1018	80	125	1040	21	202
CPI 091411	Mottled brown	13·0	61	23	663	82	102	910	20	207
Hero	Mottled brown	16·5	97	17	789	85	137	950	23	243
WT 12078	Mottled purple	13·8	75	43	565	150	115	930	120	211
WA 571	Mottled purple	23·7	78	24	888	92	102	1020	26	214
Zelka	Wrinkled green	30·0	98	1	1087	130	85	1030	28	181
COB 190175	Wrinkled orange	29·7	102	3	1034	110	73	1000	30	181

TABLE 6
Correlation of cooking quality parameters for whole seed and splits of field peas

Characteristic	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
(1) Seed size	1·000								
(2) Moisture	0·598**	1·000							
(3) Hardness of seed coat	−0·281	0·085	1·000						
(4) Water absorption of splits	0·195	0·136	0·087	1·000					
(5) Cooking time of splits	−0·186	0·030	0·546**	−0·184	1·000				
(6) Solid dispersion of splits	−0·165	−0·149	0·208	0·144	−0·069	1·000			
(7) Water Absorption of whole seed	0·279	0·002	−0·817**	0·170	−0·339	−0·172	1·000		
(8) Cooking time of whole seed	0·370	0·311	0·047	−0·224	0·572**	−0·402	−0·008	1·000	
(9) Solid dispersion of whole seed	−0·274	−0·181	−0·120	0·297	−0·153	0·501**	0·219	−0·460*	1·000

* Significant at 5% level; ** significant at 1% level.

cooking time for whole seeds was much shorter for blue and dun types (91 and 96 min) than for wrinkled (120 min) white (109 min) and mottled (102 min) types. These differences disappeared when splits were cooked. Wrinkled types lost less solids into cooking water than other types, both for whole seeds and splits.

Several seed characteristics affect the cooking process in pulses which relates to softening the cotyledon fibre, starch and proteins. It was expected that some of these would provide a means for predicting cooking time. Correlations among these characteristics and cooking time are given in Table 6. Unexpectedly, seed size was not correlated with cooking times of whole seeds or splits. Williams and Singh (1987) reported a highly significant positive correlation between seed size and cooking time of chickpea genotypes. Seed size was positively correlated with initial moisture content. Hard seed coatedness was not correlated with cooking time of the whole seed but was positively correlated with cooking time of splits, suggesting that the seed coat was not a factor in the seeds failing to hydrate. This characteristic (hard seed coatedness), commonly used in the industry to define non-hydrating seeds, needs to be reconsidered.

As expected, water absorption was negatively and significantly correlated ($r = -0{\cdot}817$, $P = 0{\cdot}01$) with hard seed coatedness, but unexpectedly, not with cooking time of whole seeds or splits. Chavan *et al* (1983) and Parades-Lopez *et al* (1991) had both reported water absorption to be correlated with cooking time of beans. For whole seeds, solids dispersion was negatively and significantly correlated ($r = -0{\cdot}460$, $P = 0{\cdot}05$) with

TABLE 7
Effect of presoaking in different salt solutions on cooking time and cooking losses of whole seed and splits of dun type field pea market sample[a]

Treatments	*Whole seed*		*Splits*	
	Cooking time (min)	*Cooking losses ($g\ kg^{-1}$)*	*Cooking time (min)*	*Cooking losses ($g\ kg^{-1}$)*
Control	82	181	34	285
Water	76	85	30	293
Sodium bicarbonate 10 g kg^{-1}	76	139	18	304
Sodium bicarbonate 20 g kg^{-1}	74	76	18	429
Sodium chloride 10 g kg^{-1}	74	109	24	325
Sodium chloride 20 g kg^{-1}	76	119	22	243
Sodium tripolyphosphate 10 g kg^{-1}	72	141	18	273
Sodium tripolyphosphate 20 g kg^{-1}	72	142	18	320
Sodium bicarbonate, chloride tripolyphosphate mix 15 g kg^{-1}	78	139	20	373

[a] All samples soaked for 1 h prior to cooking.

cooking time. This suggests that some quicker-cooking varieties more easily lost material into the cooking water as in the test method for solids dispersion, all genotypes were cooked for the same time. Future work in this field could include studying the nature of this material as it could be of nutritional significance.

Presoaking pulses in water or salt solution before cooking has been suggested as a means of shortening cooking time (Rockland *et al* 1979). Results in the present study (Table 7) showed that presoaking in sodium chloride, sodium bicarbonate and sodium tripolyphosphate solutions all considerably reduced cooking time for whole seeds and for splits. The largest improvement was found with sodium tripolyphosphate (10% reduction for whole seeds and 45% for splits). Higher salt concentrations did not result in further reductions in cooking times (data not shown). Sodium carbonate was found effective in reducing cooking time of some pulses (Chavan *et al* 1983); however, attempts to use this salt were abandoned in this study when seeds became discoloured during cooking in this salt. Cooking losses were reduced after soaking whole seed in water or salts, the largest reduction being found with sodium bicarbonate. However, when splits were soaked in this salt, cooking losses increased, while other soaking media had little effect. Further work in this area is required to determine any residual sodium in the soaked seeds.

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