Influence of heat processing on functional properties of Australian wattle seed (*Acacia victoriae* Bentham) extracts

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Abstract

Whole wattle (*Acacia victoriae* Bentham) seed was extracted with water before or after a soaking/heat treatment regime designed to destroy its protease inhibitors. The yield, composition and physical properties of these extracts were measured and they were then subjected to an analysis of their functional properties, which included emulsion and foam formation and stabilization, solubility at different pH values and gelling ability. Processing of soaked wattle seed at 100 °C for 30 s led to a much reduced extract yield and viscosity at both pH 4 and 7, decreased its water-soluble carbohydrate content but increased its protein content, and solubility under alkaline conditions. Processing of wattle seed before extraction also led to increased emulsion droplet size and reduced emulsion stability, the differences being more pronounced in emulsions formed with 20% oil compared with 50% oil-in-water emulsions. Comparatively, the emulsions formed using extract from non-processed wattle seed were very stable at both 20% and 50% oil levels, especially at pH 7 where the enhanced viscosity of the extract predominated. All extracts had very low foaming capacity, and gelation did not occur in any of the samples even at 10% (w/v) extract concentration.

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1. Introduction

*Acacia victoriae* (Bentham), also known as prickly wattle, is one of the most common of the approximately 960 species of wattle plant found in Australia (Maslin & McDonald, 2004). Its current food use is limited to the seeds being roasted at a high temperature before being incorporated into beverages, baked products and dairy foods, mainly as a flavouring agent (Maslin, Thomson, McDonald, & Hamilton-Brown, 1998; Maslin & McDonald, 2004). It has been suggested, by anecdotal evidence from mostly wattle seed producers and some food manufacturers, that the seed extract may possess some food-functional properties. This is a plausible scenario considering wattle seed composition, which shows a high concentration of proteins and carbohydrates (Brand, Cherikoff, & Truswell, 1985). It is, therefore, conceivable that this product could perform an even wider role within the food industry if its functional properties could be elucidated. Therefore, in a recent publication (Agboola, Ee, Mallon, & Zhao, 2007), we described the characterization of water extracts from Australian wattle seed in terms of its protein profile and emulsifying properties under varying processing conditions. The extract was predominantly made up of medium-sized proteins and soluble carbohydrates, and was able to stabilize oil-in-water emulsions even at low protein concentrations, under retort conditions, and at low ionic strength. Furthermore, smaller emulsion droplets were formed under acidic pH conditions. It is, however, not clear how the individual extract components (e.g., proteins and carbohydrates) stabilize the emulsion droplets as data on surface coverage and the partitioning between proteins and soluble carbohydrates in the two-phase system are not available.

It is well established that seeds from leguminous and cereal plants possess anti-nutritional activity, which is
derived from their evolutionary defence mechanism to ward off predators (Srinivasan, Giri, Harsulkar, Gatehouse, & Gupta, 2005). This, however, detracts from their utilization as human food because anti-nutritional factors, by definition, can interfere with absorption and utilization of nutrients (Liener, 1980). Although wattle seeds have been consumed by Australian Aboriginal communities for centuries (Seigler, 2002), it is important to establish the nature and content of these anti-nutritional factors if wattle seed extracts are to be considered for incorporation into processed foods as major ingredients. Consequently, we have studied the character of the protease inhibitors in wattle seed (Ee, Zhao, Rehman, & Agboola, 2008) and reported that the extent of processing required to completely inactivate trypsin and α-chymotrypsin inhibitors in soaked wattle seed samples could be limited to only 30 s at 100 °C (boiling).

Heat processing is a well-established method for inactivating protease inhibitors, owing to their effect on inhibitor (usually protein) conformation. However, it has also been reported to be quite influential on the protein functional properties (Halling, 1981), the extent, of course, depending on the level of protein denaturation (Sikorski, 1997). Limited denaturation could be beneficial, while extensive protein denaturation has been reported as being detrimental to measured functional properties, especially in relation to surface properties (Damodaran, 2005). Therefore, in this study, we report on the relative roles of major components of wattle seed extract in stabilizing the oil-in-water emulsions reported earlier (Agboola et al., 2007). Other functional properties were also measured and the influence of heat-processing conditions designed to inactivate the protease inhibitors on emulsification, emulsion stability, solubility, gelling and foaming properties was investigated. The overall objective was to evaluate the viability of wattle seed extracts as mainstream functional food ingredients that satisfies reasonable consumer safety concerns.

2. Materials and methods

2.1. Materials

Whole wattle (A. victoriae Bentham) seeds were supplied by Outback Bushfoods, Alice Springs, NT, Australia. Commercial-grade canola oil was purchased from a local supermarket in Wagga Wagga, NSW, Australia. All other reagents and chemicals were supplied by Sigma-Aldrich, Castle Hill, NSW, Australia.

2.2. Extraction of wattle seed components

Untreated whole wattle seeds (control) were ground using a ZM 100 ultra-centrifugal mill (Retsch GmbH, Germany) and passed through a 0.11 mm mesh. They were then extracted (ratio 1:10) with distilled water or 0.01 M sodium phosphate buffer at different pH values (pH adjusted to between 3 and 9 by either 1 M HCl or 1 M NaOH) by stirring for 1 h at room temperature (25 °C) (Agboola et al., 2007). To examine the influence of soaking and heating on the functional properties of the extracts, whole wattle seeds were treated by soaking in distilled water overnight, after which fresh distilled water or 0.01 M sodium phosphate buffer at different pH values (pH adjusted to between 3 and 9 by either 1 M HCl or 1 M NaOH) in the ratio of 1:10 (original seed weight to distilled water) was added. The seeds were blended for 2 min into a smooth slurry and stirred for 1 h at room temperature. In another treatment, whole wattle seeds that were soaked overnight were heated at 100 °C in water bath (Julabo Labortechnik GmbH, Germany) for 30 s. After cooling rapidly with cold water, these seeds were treated in a similar way to the soaked (only) counterpart. Each slurry was then centrifuged at 3000 g for 10 min and the supernatant was collected as crude extract. All supernatants, including from untreated (control), soaked and soaked–heated samples, were freeze dried using a Martin Christ Alpha 1-4 Freeze Dryer (Biotec International, Germany).

The extracts of wattle seeds were characterized by yield and proximate analysis following the methods described elsewhere (Agboola et al., 2007).

2.3. Measurement of protein solubility

The method of Lee, Morr, and Ha (1992) was used to determine the protein solubility. A 1% (w/v) solution of the freeze-dried wattle seed extract in 0.01 M phosphate buffer (pH adjusted to between 3 and 9 with either 1 M HCl or 1 M NaOH, respectively) was prepared and stirred for 5 min, after which it was centrifuged at 10,000 g for 30 min. The protein solubility was calculated as the percentage of protein in supernatant divided by the percentage of total protein in the original solution (Agboola, Ng, & Mills, 2005). The protein analysis for the solubility test was carried out using a Biuret test kit (Sigma Diagnostics, Micro Protein Determination, procedure no. 690). The 0.01 M phosphate buffer was used instead of sodium chloride solution in preparing the standards because phosphate buffer was used as extraction medium.

2.4. Emulsifying properties of wattle seed extracts

Oil-in-water emulsions containing 20% (v/v) and 50% (v/v) canola oil were prepared by adding the appropriate amount of supernatant of untreated whole wattle seed extract, soaked seed extract and soaked–heated seed extract in 0.01 M phosphate buffer at pH 4 or 7. After mixing the oil with the given volume of supernatant, the coarse emulsion was passed through a two-stage high-pressure homogenizer (Niro Soavi, Parma, Italy) with a total pressure of 28.6 MPa while keeping the first stage pressure constant at 14.3 MPa, to form the emulsion. Each emulsion was passed through the homogenizer three times at the given pressure to ensure complete dispersion of the oil.
2.5. Characterization of emulsions

All the emulsions were stored in a refrigerator (4 °C) with their physical properties measured daily for up to 7 days. Each preparation also had 0.05% (w/v) sodium azide added to prevent microbial contamination. Every day, the emulsions were visually examined for signs of creaming, oiling off or other physical separation attributes. Creaming was indicated if there was any change in turbidity between the top and lower layers of the emulsion, while oiling off relates to the presence of any free oil on the surface of the emulsion stored in a test tube (Walstra, 1996). The height of separation layer was also measured relative to the total emulsion height as an indication of stability. Furthermore, the droplet size distribution and the weight–volume emulsion height as an indication of stability. The relative density of canola oil at 20 °C (0.916 g/cm³) was used to calculate the surface concentration (Lee et al., 1992).

2.6. Measurement of surface concentration of the emulsions

Surface concentration was determined at two different extract concentrations equivalent to 0.73% and 1.11% (w/v) proteins in 20% oil-in-water emulsions or 0.29% and 0.44% (w/v) in corresponding 50% oil-in-water emulsions. This was carried out according to a modification of the depletion factor method using a centrifugal force/time regime (Agboola, Singh, Munro, Dalgleish, & Singh, 1998). The emulsion was centrifuged at 3000 g for 10 min to remove most of the cream. The subnatant was then centrifuged again at the same condition to separate the remaining cream from the serum phase. The serum (subnatant) was finally analysed for total nitrogen (TN) on a Leco CNS-2000 System (Leco Corp., St. Joseph, MI, USA) or for water-soluble carbohydrates (WSC) using the AOAC (1996) methods. Surface nitrogen (or WSC) was determined by subtracting the TN (or WSC) contents of an aliquot of extract solution used in making equivalent amount of emulsion, from serum TN (or WSC) of the total emulsion. A factor of 6.25 was used to convert the milligrams of nitrogen to milligrams protein per cubic centimetre (cm³) of oil. From the Mastersizer data, specific surface area (SSA) in square metre per gram of oil was obtained for each freshly prepared emulsion and was used to calculate the surface concentration (I) in milligrams of protein or WSC per square metre as follows:

$$I = \frac{\text{mg of protein or WSC/g of oil}}{\text{SSA (m}^2/\text{g of oil)}}.$$

The relative density of canola oil at 20 °C (0.916 g/cm³) was used to convert SSA (in m²/cm³) to m²/g.

2.7. Measurement of apparent viscosity

The apparent viscosity of wattle seed extracts and the emulsions formed with each extract at different pH values were measured by using the narrow gap rotational geometry of a Brookfield DV-II+ viscometer (Brookfield Engineering Laboratories, Inc., MA, USA) at room temperature (25 °C) following the manufacturer’s instructions. Readings were taken on the same day of extraction or of emulsion preparation in triplicate and average values and standard deviations were reported.

2.8. Foaming capacity and stability

A 100 mL aliquot of the crude extract (1% w/v) was prepared in 0.01 M sodium phosphate buffer at different pH values (from pH 3 to 9). Each preparation was then blended at high speed for exactly 1 min using a 550 W blender (Breville Pty. Ltd., Sydney, Australia). Then, the entire content was transferred to a 250 mL measuring cylinder to measure the total volume height after blending. Foaming capacity was calculated as the volume of mixture after blending divided by the original volume (100 mL). A plot of foam capacity against time at 1 min intervals for up to 10 min gave an indication of foam stability (Lee et al., 1992).

2.9. Gelation concentration

The minimum gelation concentration of wattle seed extract was determined by preparing 10 mL dispersion of freeze-dried extract ranging in concentration between 1% (w/v) and 10% (w/v) with 0.01 M sodium phosphate buffer. The dispersion was thoroughly mixed using an Ultra-Turrax T25 homogenizer (Janke & Kunkel, Germany) for 5 min, and then poured into 15 mL test tube and heated at 90 °C for 30 min in a water bath. The mixture was refrigerated (4 °C) for 1 h after which the tube was inverted to determine gel formation (Agboola et al., 2005). The lowest concentration at which the sample did not fall down or slip from an inverted tube is the minimum gelation concentration (Lee et al., 1992).

2.10. Statistical analysis

All extractions and analyses were carried out at least in triplicate and the mean (with standard deviation) was reported. Data collected were subjected to analysis of variance, and means of treatments showing significant difference (p < 0.05) were subjected to Fisher’s least significant difference test.

3. Results and discussion

3.1. Processing and extraction of wattle seed

Table 1 shows the material yield and component recovery after processing and freeze drying the extracts.
The untreated whole seed was highest in solid yield (34.49 g/100 g seed sample) and WSC at 18%, but the protein content of the extract (26%) was considerably lower compared with the soaked and soaked–heated extracts. This would suggest that some WSC may have been eliminated during the soaking and soaking–heating regimes. This may also have contributed to the significant increase in the protein content of the soaked and soaked–heated extracts. These results showed that maceration of soaked or soaked–heated samples using a blender was clearly not as efficient in disintegrating the seeds and especially the hard outer coats compared with the dry milling of the whole seeds for extraction. Consequently, we believe that the whole seed extract had a lot more material from the coat compared with the processed extracts, a fact confirmed by the very dark brown colour of the whole seed extract compared with the much lighter colour of the processed extracts. The material yield and protein content of the untreated whole seed extract were very similar to our previous findings (Agboola et al., 2007), although in that study it was found that the cotyledon (seeds with coat removed) yielded a much higher amount of extract (67%), which had a considerably higher protein content (45%) than the whole seed extract.

3.2. Protein solubility

The protein solubility of wattle extract as a function of pH in the range from 3 to 9 was measured. As shown in Fig. 1, protein solubility increased considerably with pH between 4.0 and 9.0, for all the extracts. Due to the low solubility around pH 4, which was more pronounced for the untreated extract, it would be reasonable to suggest this value as being close to the isoelectric points of a majority of wattle seed proteins. The results showed, in general, that protein solubility was higher for treated seed extracts compared with the control, especially at pH ≥7. These results agree with findings on other leguminous protein extracts such as cowpea, Canavalia spp., faba bean, lentil, chickpea and dry bean where protein solubility increased as pH value changed from acidic to alkaline region (Carbonaro, Cappelloni, Nicoli, Lucarini, & Carnovale, 1997; Chel-Guerrero, Rez-Flores, Betancur-Ancona, & Vila-Ortiz, 2002; Phillips, Prinyawiwatkul, Beuchat, & McWatters, 1997).

3.3. Apparent viscosity of extracts and emulsions

Table 2 shows the apparent viscosity of untreated (control) and treated wattle seed extracts and their 20% and 50% oil-in-water emulsions at different pH values. There were no significant differences between the viscosity of soaked seed extract and soaked–heated seed extract at both pH values studied. However, for untreated whole wattle seed extracts, the viscosity at pH 7 was more than five times higher than that at pH 4. The results indicated that extracting whole seed flour that contained the outer

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### Table 1
Recovery of water extracts of wattle seed

<table>
<thead>
<tr>
<th>Sample</th>
<th>Yield (g/100 g sample)</th>
<th>Protein content (wt%)</th>
<th>Fibre content (wt%)</th>
<th>WSCa (wt%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole seed</td>
<td>34.5 ± 0.3a</td>
<td>26.0 ± 0.3a</td>
<td>&lt;0.1 ± 0.0</td>
<td>18.0 ± 0.1a</td>
</tr>
<tr>
<td>Soaked seed</td>
<td>11.4 ± 0.1b</td>
<td>35.6 ± 0.4b</td>
<td>&lt;0.1 ± 0.0</td>
<td>15.0 ± 0.1b</td>
</tr>
<tr>
<td>Soaked–heated seed</td>
<td>15.0 ± 0.2c</td>
<td>36.9 ± 0.4b</td>
<td>&lt;0.1 ± 0.0</td>
<td>14.0 ± 0.1b</td>
</tr>
</tbody>
</table>

Values in the same column with different superscripts are significantly different (P < 0.05).

aWater-soluble carbohydrates.

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### Table 2
Apparent viscosity (in mPa s) of wattle seed extracts and their emulsions

<table>
<thead>
<tr>
<th>pH</th>
<th>Sample</th>
<th>Extract (supernatant)</th>
<th>20% oil-in-water emulsion</th>
<th>50% oil-in-water emulsion</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Whole seed</td>
<td>16.0 ± 0.0a</td>
<td>21.0 ± 0.0b</td>
<td>51.5 ± 0.7d</td>
</tr>
<tr>
<td></td>
<td>Soaked seed</td>
<td>13.5 ± 0.7a</td>
<td>18.5 ± 0.7c</td>
<td>34.5 ± 0.7e</td>
</tr>
<tr>
<td></td>
<td>Soaked–heated</td>
<td>13.0 ± 0.7d</td>
<td>19.5 ± 0.7e</td>
<td>36.0 ± 0.0f</td>
</tr>
<tr>
<td>7</td>
<td>Whole seed</td>
<td>72.5 ± 0.7g</td>
<td>77.0 ± 1.4h</td>
<td>209.5 ± 0.7h</td>
</tr>
<tr>
<td></td>
<td>Soaked seed</td>
<td>14.0 ± 0.0b</td>
<td>21.0 ± 0.0b</td>
<td>37.0 ± 0.0c</td>
</tr>
<tr>
<td></td>
<td>Soaked–heated</td>
<td>13.5 ± 0.7g</td>
<td>21.0 ± 0.0b</td>
<td>35.9 ± 0.7c</td>
</tr>
</tbody>
</table>

Values in the same row or column with different superscripts are significantly different (P < 0.05).
coat portion led to a significant increase in extract viscosity at pH 7. As discussed above, the outer coats did not significantly contribute to the extracts from soaked seed or soaked–heated seed extracts. The results also showed that influence of pH on the seed coat extracts led to significant changes in viscosity and interactions in aqueous systems. This clarifies some of the findings from our previous studies on water extracts from untreated seeds which suggested that influence of pH on protein solubility (suspension viscosity) could have been responsible for increased viscosity at pH 7 (Agboola et al., 2007). It is apparent from this study, however, that based on the relatively low viscosity of the whole seed extract at pH 4, and of the treated seed extracts at both pH 4 and 7, the non-protein content of the extract was probably more involved than the protein component of the extract.

In general, the viscosity values were higher in emulsions prepared with 50% oil than those containing 20% oil. This was also true in emulsions made with untreated seed extract at all pH values, but especially at pH 7 where the viscosity was more than three times higher than those observed for any other sample in the 20% oil-in-water emulsions. For 50% oil-in-water emulsions, the viscosity was similarly markedly higher in emulsions prepared from untreated seed extract at all pH values; at pH 7, the viscosity was more than four times higher than at pH 4. Overall, both extracts and emulsions from whole seed samples had higher viscosity than their counterparts from soaked and soaked–heated seeds irrespective of extraction or emulsification conditions.

3.4. Emulsifying properties of wattle seed extracts

Data plotted in Fig. 2 revealed that emulsions from soaked and soaked–heated wattle seed extracts were generally less stable than those from untreated whole seed extracts irrespective of emulsification temperature and oil content. In most of these emulsions, instability progressed very quickly, mostly within 1 or 2 days of storage after which there were no further changes. Figs. 2C and D,

![Graphs showing emulsifying properties of wattle seed extracts](image-url)
However, show that emulsions formed at pH 7 using untreated whole wattle seed extract were stable throughout the 7 days of storage while those prepared with soaked and soaked–heated extracts were destabilized after only 1 day of storage. Emulsions formed at pH 4, on the other hand, still showed the same trend but those prepared from untreated whole seed extract were not as stable as at pH 7, with significant separation after only 1 day of storage, which increased gradually thereafter. Emulsions formed with 20% oil using processed seed extracts were generally less stable than those containing higher oil content (50%). These emulsions showed greater than 30% separation, rising to above 50% separation at pH 4, whereas the highest separation from 50% oil emulsions was about 25%.

The $d_{43}$ particle size average and size distribution, evaluated as functions of different extracts (control, soaked seeds and soaked–heated seeds), pH, storage periods and percentage of oil-to-water, are shown in Figs. 3 and 4, respectively. Results indicated that 50% oil-in-water emulsions made at pH values of 4 and 7 were larger in particle size than the 20% oil counterparts. Results also suggested that the higher oil content and the increased interfacial area created without a sufficient amount of surfactant (protein level reduced from 1.11% for 20% oil-in-water emulsions to 0.44% for 50% oil-in-water emulsions) led to significant change in the size of droplets. Consequently, 20% oil emulsions had a bimodal distribution pattern with low frequency in the size range of 10 μm and above, the majority falling within 0.1 and 10 μm (Figs. 4A and C). In comparison, emulsions containing 50% oil showed tri-modal distribution patterns with a significant proportion in the 10–100 μm size range (Figs. 4B and D).

However, these 50% oil-in-water emulsions exhibited less separation compared with 20% oil-in-water emulsions, especially at pH 7, where the emulsion did not show any separation. This could be due to the considerably high viscosity of the dispersion medium that results in higher kinetic stability of the emulsion (Benichou, Aserin, & Garti, 2002). The high oil content could also have led to the phenomenon of hindered separation whereby the droplets, though large, are physically prevented from coming together and separating (Darling & Birkett, 1987). Becher (2001) also claimed that gravitational separation is dependent on the volume fraction (φ) of the dispersed phase, and is usually slow in concentrated emulsions (φ > 0.74) due to the hindered separation effect.

This study indicated that the pH 7 extract, which was prepared from untreated whole wattle seeds (at a very low solid concentration of about 2%), presented very high viscosity and attained a weak gel-like appearance after overnight storage at 4 °C. However, the apparent viscosity of extracts prepared at pH 4 was not significantly different from that of the other extracts (Table 2). We believe that the carbohydrates from the seed outer coat played an important role in conferring high viscosity and thus

![Fig. 3](https://example.com/fig3.png)

**Fig. 3.** Effect of storage time on average particle size ($d_{43}$) of 20% (A and C) and 50% (B and D) oil-in-water emulsions formed with water extract from untreated whole wattle seed (●), soaked seed (■) and soaked–heated seed (▲) at pH 4 (A and B) or pH 7 (C and D).
emulsion stability. According to Stoke’s law, the higher the viscosity of the continuous phase, the slower the rate of separation (Damodaran, 2005; McClements, 1999), and both sets of emulsions at pH 7 exhibited no discernible serum separation over the observational time-scale (Fig. 2). Although large oil droplets were formed in emulsions with high viscosity continuous phase due to higher deformational energy requirement (McClements, 1999; Walstra, 2003), formation of networks with consequence for emulsion stability prevented the oil droplets from being so close to each other, preventing coalescence and phase separation. However, for the emulsions that were prepared from soaked seed extracts and soaked–heated seed extracts, the outer coat did not participate in the extraction process at all pH values. This presumably led to low continuous phase viscosity even at pH 7, with the emulsions exhibiting phase separation on the second day of storage. The relatively low protein content in the system would have led to very low surface coverage by the protein molecules, leading to droplet coalescence and increased rate of creaming (Nakai & Modler, 1996).

The results in this study seemed to confirm that untreated whole wattle seed extract was very suitable for emulsification at both pH 4 and 7 as previously described (Agboola et al., 2007). However, although the average size of freshly formed emulsion droplets was much lower at pH 4, longer-term stability was significantly enhanced at pH 7 presumably due to increased serum-phase viscosity. Furthermore, our attempt to determine the nature of interfacial constituents was not very successful, presumably due to the very low concentration of polymers in the system. Surface coverage of both proteins and water-soluble carbohydrates was negligible, even in 50% oil-in-water emulsions that had much smaller surface area. The interfacial total protein content in the 20% oil-in-water emulsions that prepared with untreated whole wattle seed extract were determined to be only 1.11%, while it was 0.44% in the 50% oil-in-water emulsions. Similarly, the WSC contents were 0.78% and 0.31%, respectively. It would be desirable in future studies to increase the protein (and WSC) contents in the systems so that statistically valid surface concentration data can be determined. It is

Fig. 4. Typical particle size distributions of 20% (A and C) and 50% (B and D) oil-in-water emulsions formed with water extract from untreated whole wattle seed (●), soaked seed (■) and soaked–heated seed (▲) at pH 4 (A and B) or pH 7 (C and D) throughout the 7 days of storage at 4 °C.
significant, however, that stable emulsions could be formed at such low levels of polymeric materials especially from the whole wattle seed extract.

3.5. Foaming capacity and stability

Fig. 5 shows the foaming capacity of the wattle seed extracts as well as the stability of the foams over a 10-min period of observation. Results suggested that wattle seed extract conferred very low foam capacity, which also explained the exhibited foam stability in all samples at the pH values studied. Generally, the foam capacities for all samples ranged between 1.0 and 1.3. In most samples, instability progressed slowly, mostly within 2 or 4 min of observation after which there were no further changes. Data also revealed that foams from soaked and soaked–heated wattle seed extracts were generally less stable than those from the whole seed counterparts irrespective of protein content. In fact, at pH 3, the foam made from whole seed and soaked–heated extracts were higher in capacity and more stable throughout the observation period. Fig. 5 also revealed, however, that soaked and soaked–heated wattle seed extracts generally had higher foaming capacity than whole seed extracts but these differences were not significant.

Results indicated that although incorporating wattle seed extract led to great stability in oil-in-water emulsions, it presented very low foam capacity and foam stability in each sample at all pH values. Comparatively, in soybean protein concentrate, the minimum foam capacity and maximum foam stability was found at pH 4 (Chau, Peter, & Wong, 1997). It is possible that in wattle seed extracts, the proteins did not unfold significantly at the interface when air was incorporated into the aqueous phase. This could be due to the fact that the proteins, which ranged between 27 and 61 kDa (Agboola et al., 2007), contain a significant amount of disulphide bonds that may prevent unfolding at the air–water interface. This would also support our suggestion with regard to the emulsion stabilization as being mostly due to the polysaccharide fraction from the outer coat and not because of the protein fraction. Polysaccharides are best known for their water-holding and thickening properties and normally do not support foaming (Dickinson, 1992), while proteins, which are able to unfold, depending on composition and conformation, would orient themselves at oil–water or air–water interfaces.

3.6. Gelation concentration

Gelation capacity was studied as a function of different extracts, pH and extract concentration. However, gelation did not occur in any of the samples under these conditions. Between pH 3 and 9, aggregation and increased viscosity of wattle seed extract suspensions were observed, but gelation did not occur even at high extract concentration levels studied. The critical factor influencing gel formation is the protein concentration (Phillips et al., 1997). For leguminous protein isolates such as pea and soybean, the minimum gelling concentration has been shown to be usually above 10% (Makri, Papalamprou, & Doxastakis, 2005; O’Kane, Happe, Vereijken, Gruppen, & van Boekel, 2004). In the present study, the protein concentrations used were below 4%, which could explain why gelation did not occur. It is also possible that the high polysaccharide content of these extracts (Table 1) prevented proper gelation of the proteins. Our current study is on the purification of the extract by salt precipitation and chromatography such that the protein content may be significantly increased. It would thus be important to investigate the effect of protein purification on the gelation and other functional properties of the protein isolates.

4. Conclusion

Our study has indicated that processing to destroy anti-nutritional factors in wattle seed before crude extraction led to much poorer functional properties, especially
emulsion stability. This was presumably due to the lack of incorporation of seed coat extracts during the extraction. Results from this study indicated that low viscosity of the treated seed extracts with respect to the whole seed counterpart appeared to be due to low contents of WSC capable of forming tri-dimensional networks. The increased stability of emulsions prepared from the whole seed extract over its treated counterpart seemed to be related to the increased viscosity of the former that resulted in the formation of smaller-sized droplets preventing rapid coalescence. The extracts formed weak foams and did not gel even at 10% (w/v) concentration. It was difficult to assess the surface coverage in the emulsions due to low polymer (protein and WSC) concentration. Our current studies focussing on extract purification, and the application of the purified and highly concentrated protein isolates in the formation and characterization of the food colloidal systems created should further enhance our understanding of wattle seed components and their roles in the formation and stabilization of these systems.

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