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Rheological properties, retrogradation behaviour and syneresis of native wheat starch-cress seed gum gel affected by preparation technique

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Abstract
In this paper, the impact of different substitution levels of cress seed gum (CSG, 0, 5, and 10%) on the rheological properties, hardness, and syneresis, of native wheat starch (NWS, 4%) gel was investigated. Regarding these mixtures two preparation techniques were used: a mixture of the powders before addition of water (a), or separate preparation of CSG solution and subsequent mixing with starch powder (b). According to the rheological test, all the samples exhibited shear-thinning flow behavior. Increasing the CSG substitution level up to 10%, especially for preparation technique (b), elevated the consistency coefficient and yield stress. After storage, syneresis of NWS-CSG gels decreased more by technique (b); Preparation of mixtures by technique (b), greatly decreased the rate of retrogradation (hardness values) of gels during storage at 4 ℃ for 5 days; The results indicated that technique (b) was more effective in modifying the properties of NWS-CSG gels.

Keywords: Functional properties - Hydrocolloid - Native wheat starch - Preparation technique.

Introduction
Starch is one of the most important polysaccharides which is effective in creating favorable properties in processed products. Among the commercial starches, native wheat starch (NWS) is very important due to its low price and easy availability but NWS is more sensitive to food processing conditions than other starches. Retrogradation is an undesirable phenomenon in some starch-based foods that causes syneresis, reduces the acceptability of food, and shortens the shelf life during storage and distribution [1]. Many studies have shown that carbohydrates imply an important role in improving syneresis, the rheological properties and textural attributes of starches, and retarding the retrogradation of starch gels [2, 3]. Cress seed gum (CSG), as an emerging galactomannan, has shown the ability to improve the textural and rheological features of food systems based on its unique properties [4]. Also, CSG exhibited good potential to reduce the hardness of starch gels after storage for one day at room temperature [5]. Preparation techniques of the starch-hydrocolloid mixture are one of the important factors which influence the rheological properties and the behaviour of starch [6]. Therefore, the objectives of this study were to determine the impact of different substitution levels of CSG (0, 5, and 10%) on the rheological properties, retrogradation (hardness), and synthesis of native wheat starch (NWS) gel (4% w/w) prepared by two techniques (powder-powder or powder-solution).

Experimental/Theoretical
NWS was supplied from Sigma Aldrich (Spain) and CSG was extracted from cress seeds. To produce starch gels, starch–gum mixtures (4% w/w suspensions of NWS with substitution of 0, 5 and 10% w/w CSG) were prepared using two techniques: powders mixing, adding water and hydrated (technique (a), NWS+CSG-P), or adding starch powder to hydrated CSG solutions (technique (b), NWS+CSG-S) and heating samples thereafter at 95ºC and then cooled to 50ºC. After cooling at 25℃ for 1 h, the rheological properties of the gel samples were performed using a Bohlin viscometer in the range of 14 to 600 s^{-1} shear rate. The viscosity-shear rate data were fitted by the Herschel-Bulkley model. The syneresis of gels was assessed after storage at 4℃ for 1 day. The textural properties of the starch gels were determined by the back-extrusion test and using a Brookfield Texture Analyzer. The test was performed at 1 mm/s rate to 50% deformation. The Hardness parameter of gels was determined after storage at 4ºC for 0, 1, and 5 days.

Results and Discussion
1. Rheological measurement: According to the Herschel-Bulkley model, all the samples confirmed non-Newtonian shear-thinning behavior, $n_H<1$, (Table 1). No significant differences were seen between preparation techniques for the pseudoplastic behavior of the NWS gels. The consistency coefficient (k_H) and yield stress (τ_{0H}) parameters were mainly influenced by the preparation technique. Using technique (b) for preparation was more effective in increasing the k_H

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values rather than technique (a). It obviously increased k_H from 0.69 to 2.14 Pa.s^n with increasing the substitution level of CSG from 0 to 10%. Probably, gum molecules interact with leached amylose molecules, produce a viscosity increase via synergism [6]. All samples had τ_{0H} that indicates the solid-like behavior of the fluid. With replacement of CSG, τ_{0H} of the NWS gel increased significantly. It was observed more for the preparation technique (b). In other words, the NWS+CSG-S gels had a more solid behavior than the others. In similarity, Mandala and Bayas (2004) 's results demonstrated increasing the viscosity, consistency and pseudoplasticity of the separate preparation of wheat starch and xanthan solutions and subsequent mixing technique [6].

2. Syneresis: The syneresis was measured to investigate the retrogradation of NWS gel during storage at 4 ºC. In the mixed gels (technique (b)), more reduction of the syneresis was observed rather than others, which was clearly at high CSG replacement. In this regard, the syneresis decreased from 32.52% to 30.43 and 24.43% by replacing NWS with 5 and 10% CSG, respectively. Hydrocolloids have high water holding capacity and probably separate hydration of CSG caused more reduction of the amount of water available for the re-crystallization of amylose and amylopectin molecules and retards the retrogradation of starch gels [7].

3. Textural properties: The evaluation of the hardness of starch gel during storage time (at 4ºC for 5 days) has shown a high correlation with the retrogradation phenomenon. As shown in Fig 2., after storage for 5 days at 4 ºC, especially in preparation technique (b), the CSG substitution with NWS reduced the rate of retrogradation. It can be stated that gum molecules inhibit leaching amylose molecules effectively and prevent retrogradation. On the other hand, it is more probable that due to the excluded volume effect of starch granules, the local concentration of CSG in continuous phase increase and phase separation of CSG–amylose polymers are promoted by preparing samples with technique (a) [6].

Conclusion

The behavior of NWS gel in the presence of CSG was affected by the mixture preparation technique. Mixtures prepared with technique (b) influenced viscosity, syneresis, and retrogradation more positively. In this regard, the viscosity and yield stress of NWS-CSG gels were increased more and its syneresis and the rate of retrogradation were decreased more.

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Table 1. Rheological parameters of native wheat starch-cress seed gum gel prepared by two techniques.

Sample	Herschel-Bulkley model Parameters				
	n_H (-)	K_H (Pa.s^n)	τ_{0H} (Pa)	R^2	RMSE
1	0.66±0.01	0.69±0.01^c	0.27±0.07^c	0.99	0.00
2	0.62±0.08	0.85±0.25^{bc}	2.09±0.20^b	0.99	0.00
3	0.55±0.03	1.58±0.11^{ab}	3.58±0.51^a	0.98	0.02
4	0.62±0.01	0.97±0.08^{bc}	3.95±0.01^a	0.99	0.00
5	0.54±0.01	2.14±0.59^a	4.19±0.32^a	0.99	0.00

1: NWS4%, 2: NWS+5%CSG-P, 3: NWS+10%CSG-P, 4: NWS+5%CSG-S, 5: NWS+10%CSG-P.

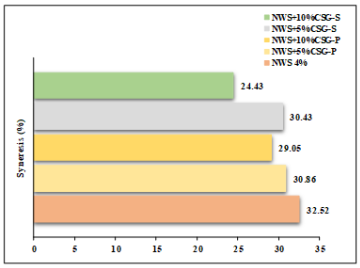

Fig 1. Syneresis of native wheat starch-cress seed gum gel prepared by two techniques.

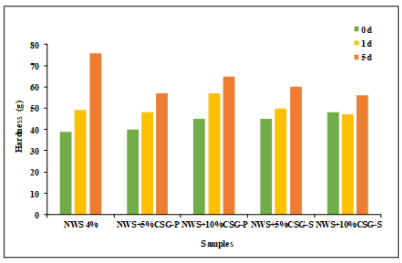

Fig 2. Hardness parameter (g) of native wheat starch-cress seed gum gel prepared by two techniques during storage time.