UNIVERSIDADE ESTADUAL DE MARINGÁ

CENTRO DE CIÊNCIAS AGRÁRIAS

Programa de Pós-Graduação em Ciência de Alimentos

PROPRIEDADES DE MISTURA DE MUCILAGENS OBTIDAS DA CASCA DO PSYLLIUM (*Plantago psyllium L*) E DA SEMENTE CHIA (*Salvia hispanica L*).

MARIANA MENCONI CHINELLATO

Maringá

2016

MARIANA MENCONI CHINELLATO

PROPRIEDADES DE MISTURA DE MUCILAGENS OBTIDAS DA CASCA DO PSYLLIUM (*Plantago psyllium L*) E DA SEMENTE CHIA (*Salvia hispanica L*).

Dissertação apresentada ao programa de Pós Graduação em Ciências de Alimentos da Universidade Estadual de Maringá, como parte dos requisitos para a obtenção do título de mestre em Ciências de Alimentos.

Maringá
2016

Dados Internacionais de Catalogação-na-Publicação (CIP)
(Biblioteca Central - UEM, Maringá – PR., Brasil)

Chinellato,Mariana Menconi
C539p Propriedades de mistura de mucilagens obtidas da casca do psyllium (*Plantago psyllium* L) e da semente chia (*Salvia hispânica* L) / Mariana Menconi Chinellato. -- Maringá, 2016.
36 f.: Il. tabs.

Orientador: Prof. Dr. Antonio Roberto Giriboni Monteiro.

Dissertação (Mestrado em Ciencia de Alimentos)- Universidade Estadual de Maringá. Centro de Ciências Agrárias. Programa de Pós-graduação em Ciencias de Alimento.

1. Ciencias de alimentos. 2.Interações de Microestruturas - Processos. 3. Vegetais. I. Monteiro, Antonio Roberto Giriboni,orient. II. Universidade Estadual de Maringá. Programa de Pós-graduação em Ciencias de Alimento. IV. Título.

21.ed. 664

Cicilia Conceição de Maria
CRB9- 1066

Orientador
Prof. Dr. Antonio Roberto Giriboni Monteiro

MARIANA MENCONI CHINELLATO

"PROPRIEDADES DE MISTURA DE MUCILAGENS OBTIDAS DA CASCA DO PSYLLIUM (*PLANTAGO PSYLLIUM* L.) E DA SEMENTE CHIA (*SALVIA HISPANICA* L.)"

Dissertação apresentada à Universidade Estadual de Maringá, como parte das exigências do Programa de Pós-graduação em Ciência de Alimentos, para obtenção do grau de Mestre em Ciência de Alimentos.

Profa. Dra. Grasiele Scaramal Madrona

Profa. Dra. Tatiana Colombo Pimentel

Prof. Dr. Antonio Roberto Giriboni Monteiro
(Orientador)

Maringá - 2016

BIOGRAFIA

Mariana Menconi Chinellato, filha de Célia Regina Menconi Chinellato, nasceu em 14 de janeiro de 1986, na cidade de Limeira, São Paulo.

Graduou-se em janeiro de 2011, como Engenharia de Alimentos pela Universidade Estadual de Maringá-UEM campus sede, com a defesa do trabalho intitulado "Elaboração de banco de dados de julgadores para realização de análises sensoriais", orientada pela professora Ph.D. Miriam Carla B. Ambrosio Ugri.

Na graduação participou de projetos de extensão na área de carnes e polpa de frutas congeladas. Foi membro dirigente no CREA-JR e técnica do laboratório de Tecnologia de Alimentos. Organizou diversos eventos como ENEEALI (Encontro Nacional de Engenharia de Alimentos) no ano de 2010 em Foz do Iguaçu e a SEMANEA (Semana Acadêmica de Engenharia de Alimentos) no ano de 2009 na cidade de Maringá, Paraná.

Tem experiência nas áreas de vegetais atuando principalmente com os seguintes temas: Carboidratos formadores de gel oriundos de fontes vegetais, processamento de alimentos por extrusão, analise sensorial quantitativa, tecnologia de produção de pães e tecnologia de produção de cervejas artesanais.

Dedico
esta obra a todos os cientistas que
enxergam o conhecimento como um bem de
todos e que compartilham suas experiências
para a evolução da Ciências de Alimentos.

AGRADECIMENTOS

Agradeço a Universidade Estadual de Maringá ao Programa de Pós-Graduação em Ciências de Alimentos pela disponibilização do curso que tanto agregou na minha jornada profissional.

Agradeço a Fundação CAPES pelo apoio financeiro.

Agradeço ao Prof. Dr. Antonio R. G. Monteiro pela confiança e apoio incondicional nas atividades e pela amizade conferida.

Agradeço meus colegas de trabalho Diego, Dalany, Kimberli, Bruna e Juliana pela troca de experiência, auxilio nas atividades e desenvolvimento de trabalhos nas diversas áreas de Ciências de Alimentos.

Agradeço a Camila Sampaio Mangolim e André Monge Neto pelo acompanhamento das atividades deste trabalho, pela disponibilização de tempo para a execução de análises, por compartilhar suas experiências na área e por me incentivar em todo momento com palavras de coragem e compreensão.

Agradeço meus amigos Camila, André, Rodrigo, Natalia, Juliana e Diego pelos 10 anos de amizade, pelo companheirismo e pelas incontáveis horas agradáveis que passamos juntos.

Agradeço a Michael Van Staveren por contribuir generosamente com seus conselhos e sua amizade única que me trouxe força para seguir forte no meu objetivo.

Agradeço aos meus familiares Celia Regina Menconi, Antonieta Luiza Menconi e Dalva Aparecida Menconi pelo amor incondicional, pelo apoio e pelo carinho. Agradeço a Daniele Chinellato e Renieri Chinellato pelos laços de amizade e momentos de alegria.

Agradeço a Brahma Kumaris por me trazer o conhecimento e a prática espiritual que tanto me auxiliou na execução das atividades.

Agradeço a Deus que com toda sua benevolência ajudou a reconhecer meu potencial mais elevado, me trouxe calma nos momentos de estresse, me inundou com amor nos momentos de conflito e me trouxe a lembrança da paz que continua me transformando em uma pessoa melhor todos os dias.

APRESENTAÇÃO

Esta dissertação de mestrado está apresentada na forma de um artigo científico

AUTORES: Mariana Menconi Chinellato e Antonio Roberto Giriboni Monteiro

TÍTULO: Properties of mucilage blends using psyllium husk (*Plantago psyllium L*) and chia seed (*Salvia hispanica L*).

REVISTA: Food and Bioproducts Processing (Qualis B1)

GENERAL ABSTRACT

INTRODUCTION. Hydrocolloids are widely used in food industry as they have ability to retain water, are notable thickeners and gelling, have capacity of synerese controlling and stabilize emulsions. Psyllium husk and chia seed are sources of those hydrocolloids and the physicochemical properties of their mucilage them an emerging ingredients in the manufacture of bread, cakes and desserts as substitute of fat ingredients. Some polysaccharide gels may have weak interactions that, in some cases, are strengthened by the use of mixtures of polysaccharides called mixed gels. An example is the case of dilute solutions of xanthan gum and locust beans, which do not exhibit significant shear stress, but together they do.

AIMS. This thesis aimed to investigate the chia and psyllium mucilage properties when mixed in different proportions and also to check for changes in these features when these mucilage are extracted together.

MATERIAL E METHODS. Psyllium husk (P) and chia seed (C) from the respectively species *Plantago psyllium L* and *Salvia hispanica L*, were obtained in a local market and sent to Cereals Technology laboratory to be storage under room temperature. The mucilage extraction consisted in an aqueous method. Temperature, time and seed/water ratio were settle based in the literature previous studies. Two different methods were used to join the mucilage: blending and combining water extraction in which the raw materials were added and extracted together. Six treatments using mucilage powders of psyllium husk (P) and chia seed (C) were prepared. The blending range was: (T1) 100% P; (T2) 75% P, 25% C; (T3) 50% P, 50% C; (T4) 25% P, 75% C and (T5) 100% C. The combined mucilage was denominated T6. For a complete homogenization, each treatment was dissolved in distilled water, scattered using a mixer, and freeze-dried for 48 hours (-50^{o}C). Factors such as total carbohydrate content, ^{o}Brix, pH, oil holding capacity, loss of solubility were used to investigate the mucilage interactions. The mucilage blends profile were also raised as the thermal characteristics, viscosity and the attenuated total reflection (ATR) spectra. In order to compare samples, analysis of variance (ANOVA) followed by the Tukey test allowed the distinction of the treatments to 5% significance level.

RESULTS E DISCUSSION. The aqueous extraction yield for chia, psyllium and combined mucilage were respectively 9.03% of dry chia seed mass, 47.4% of dry psyllium husk mass and 21.98% of dry chia seed and dry psyllium husk mass. The pH, ^{o}Brix and oil-holding capacity showed no significant difference between the reconstituided samples. Regarding to carbohydrates content, T5 results were significantly higher than the others. The psyllium mucilage resulted in a solubility of 6.98% (T1) while the chia mucilage was 51.26% (T5). By this fact, psyllium uses most of its mucilage to form the gel chain while chia mucilage may loss the major part of it after centrifugation. Tests conducted to conclude that the combined fraction is consistent with the individual mixed one in a proportion of 32% P and 67% C. The TGA plot of the samples showed thermal effects resembling to that of a natural hydrogel. An early endothermic loss assigned has been reported by the loss of absorbed moisture. Two stages of decomposition were observed for all samples. The first is responsible for the major breakdown of the polymer chain. The second decomposition stage is characterized by a decreasing curve up to the final temperature of 600^{o}C. The char yield average was 38.68%. The mucilage of all treatments were found to have shear thinning properties. Three shear rate points (2.72s^{-1}, 7.82s^{-1} and 14.96s^{-1}) of the viscosity curve were compared. Once the chia mucilage concentration is raised, the viscosity has a downward trend from T1 to T5. SampleT6 presented unexpected behaviour presenting the highest viscosity value of the blends indicating that

aquous combined extration acts differently than blending process. Similar ATR spectra were obtained for psyllium and chia mucilage on previous studies. In general, the bands in certain regions emerge or become more visible as it adds the different mucilage. Sample T6 did not follow the trend of the mixtures and presented in most regions similar spectra to the psyllium mucilage. Assuming that the molecular structure, among other factors, influences the properties of a polymeric gel, the ATR spectra may explain the T6 viscosity behavior above expectation since it conformation is similar to T1.

CONCLUSION. Blending chia and psyllium mucilage behaves differently than the combined extraction as the viscosity resulted of combined mucilage was higher than expected being the highlight of this work. As the industry seeks to leverage factors, such as thickening, without adding artificial ingredients, combined extraction process may prove to be interesting in this case. The ATR spectra was an important tool to investigate the causes of the increased viscosity by displaying, on the molecular level, the similarities with the highest viscosity samples structures.

Key words: hydrocolloid, TGA, DSC, viscosity, ATR.

RESUMO GERAL

INTRODUÇÃO. Os hidrocoloides são amplamente utilizados na indústria alimentícia uma vez que estes possuem a capacidade de reter água, são notáveis espessantes e geleificantes, têm a capacidade de controlar sinérese e também controlam e estabilizam emulsões. A casca de psyllium e as sementes de chia são fontes desses hidrocoloides e as propriedades físico-químicas de suas mucilagens transformaram estes em emergentes ingredientes para a substituição de gordura na fabricação de pães, bolos e sobremesas. Alguns tipos de gel de polissacarídeo podem ter interações fracas que, em alguns casos, são reforçadas pela utilização de misturas de polissacarídeos chamados géis mistos. Um exemplo é o caso de soluções diluídas de goma de alfarroba e xantana, que não apresentam a tensão de cisalhamento significativa, mas em conjunto o fazem.

OBJETIVOS. Este trabalho propõe uma investigação das propriedades das mucilagens de chia e de psyllium quando misturadas em diferentes proporções e também verifica se há alteração dessas características quando essas mucilagens são extraídas em conjunto.

MATERIAIS E MÉTODOS. Psyllium husk (P) and chia seed (C) das respectivas espécies *Plantago psyllium L* e *Salvia hispanica L*, foram obtidos em um mercado local e enviados ao Laboratório de Tecnologia de Cereais para serem armazenados em condições normais ambientes. A extração das mucilagens consistiu em um método aquoso. Temperatura, tempo e proporção de água/sementes foram fixadas com base em trabalhos anteriores da literatura. Foram utilizados dois métodos diferentes para combinar as mucilagens: mistura e extração combinada onde as matérias primas foram adicionadas em um mesmo sistema de extração. Fatores como o conteúdo total de carboidratos, ºBrix, pH, capacidade de retenção de óleo e perda por solubilidade foram usados para investigar as interações das mucilagens. Foi também levantado o perfil dessas misturas de mucilagens quanto as características térmicas (TGA e DSC), a viscosidade e o espectro de reflexão total atenuada (ATR). A fim de comparar amostras, análise de variância (ANOVA) seguida pelo teste de Tukey, foi utilizada permitindo distinguir os tratamentos a um nível de significância de 5%.

RESULTADOS E DISCUSSÃO. O rendimento de extração aquosa das mucilagens de chia, psyllium mucilagem combinada foram, respectivamente, 9,03% da massa seca semente de chia, 47,4% da massa seca de casca de psyllium e 21,98% da massa seca das sementes de chia seca mais psyllium. Parâmetros da mucilagem reconstituída com pH, ºBrix e capacidade de retenção de óleo, não apresentaram diferença significativa entre as amostras. No que diz respeito ao teor de carboidratos, T5 apresentou valores significativamente elevados (13,14 g/L) se comparado aos demais (±8,25). A mucilagem de psyllium resultou em uma solubilidade de 6,98% (T1), enquanto a chia foi de 51,26% (T5). Sendo assim, ao que parece o psyllium utiliza a maior parte da sua mucilagem para formar a cadeia gel enquanto a mucilagem de chia pode perder a maior parte desta após a centrifugação. Teste de solubilidade permitiu inferir que a fracção combinada é consistente com uma mistura de mucilagens na proporção de 32% psyllium e 67% chia. O TGA das amostras mostrou efeitos térmicos que se assemelham ao de hidrogéis naturais. Uma perda endotérmica precoce atribui-se à perda de humidade absorvida. Foram observados dois estágios de decomposição para todas as amostras. O primeiro e principal é responsável pela quebra da cadeia de polímero. A segunda etapa de decomposição é caracterizada por uma curva decrescente até a temperatura final de 600ºC. A média geral das amostras quanto ao teor de cinzas foi 38,68%. Quanto a viscosidade, todas as amostras apresentaram um comportamento de redução da viscosidade a medida que se aplicou a taxa de cisalhamento. Três pontos da taxa de cisalhamento (2.72 s^{-1}, 7.82 s^{-1} e 14.96 s^{-1})

foram comparados. Uma vez que a concentração de mucilagens chia é levantada, a viscosidade tem uma tendência de queda de T1 para T5. T6 apresentou um comportamento inesperado apresentando valor mais elevado do que as outras misturas. A extração aquosa quando combinada age de forma diferente que o processo de mistura individual. Espectros similares aos da literatura foram obtidos com a técnica de ATR para as mucilagens de psyllium e chia. Em geral, as bandas em certas regiões emergem ou tornar-se mais visíveis uma vez que se adiciona a mucilagem diferente. A amostra T6 não seguiu a tendência das misturas e apresentou em grande parte das regiões, espectros semelhantes ao da mucilagem do psyllium. Partindo do princípio que as estruturas moleculares, entre outros fatores, influenciam as propriedades de um gel polimérico, o ATR pode explicar o comportamento acima do esperado da viscosidade de T6 uma vez que este é bem semelhante conformação de T1 (amostra de maior viscosidade).

CONCLUSÃO. As propriedades das misturas das mucilagens de chia e psyllium se comportam de forma diferente dependendo da forma como são misturadas. Na extração combinada a viscosidade resultou em um valor maior do que o esperado se destacando das demais misturas. À medida que a indústria procura potencializar fatores, tais como o espessamento, sem fazer adição de ingredientes artificiais, o processo de extração combinada pode revelar-se interessante neste caso. A análise dos espectros do ATR foi uma ferramenta importante para investigar as causas da viscosidade elevada da amostra combinada, exibindo, em nível molecular, as semelhanças estruturais com a molécula de psyllium.

Palavras chaves: hidrocoloides, TGA, DSC, viscosidade, ATR.

Properties of mucilage blends using psyllium husk (*Plantago psyllium L*) and chia seed (*Salvia hispanica L*).

Mariana Menconi Chinellato[1], Antonio Roberto Giriboni Monteiro*[2]

[1] *Postgraduate Program in Food Science, State University of Maringá (UEM), Av. Colombo, 5790 - 87020-900, Maringá, PR, Brazil, e-mail: mamenconi@gmail.com*

[2] *Department of Food Engineering, State University of Maringá (UEM), Av. Colombo, 5790 - 87020-900, Maringá, PR, Brazil.*

ABSTRACT

This paper used psyllium (P) and chia (C) mucilage blends obtained through mixing or combined extraction to investigate the interactions properties of these potential polysaccharide ingredients, important sources to the food industry as thickeners and stabilizers. We found the values of 9.03% for extraction yield, 47.4% and 21.98% for chia, psyllium, and combined mucilage. The samples were prepared as following percentages: (T1) 100% P; (T2) 75% P, 25% C; (T3) 50% P, 50% C; (T4) 25% P, 75% C and (T5) 100% C and the combined extraction mucilage was T6. Factors such as pH, °Brix, and oil-holding capacity revealed no significant difference between the samples; higher carbohydrates values were indicated for the content of chia seed (13.14 g/L). Solubility losses ranged from seven to 51.25 percent without the occurrence of an interaction effect. The thermal effects was similar to natural hydrogels and the chia mucilage was more stable during the major breakdown stage of decomposition. The corroboration of the interaction property occurred through the viscosity factor. The viscosity of the combined sample had higher values than the blended samples and the attenuated total reflection (ATR) spectra indicated more molecule conformation similarities with the psyllium than chia.

Highlights: Psyllium husk aqueous extraction presented higher crude yield compared to chia seed extraction although both results were higher than currently literature studies; ►Mass balance was used to predict the combined extraction ratio; ► Combined extraction produced mucilage with higher viscosity than expected showing this parameter as dependent on the extraction technique; ► The ATR spectra produced important evidences of the mucilage similarities pointing an explanation to the unexpected results.

Key words: hydrocolloid, TGA, DSC, viscosity, ATR.

* Corresponding author. Tel.: +55 44 3011-4401
E-mail address: antoniorgm@gmail.com (A.R.G. Monteiro)

1. Introduction

The food industry has largely employed hydrocolloids for their ability to retain water and representing remarkable thickeners and gelling in addition to the capacity to synerese controlling and stabilize emulsions (Phillips & Williams, 2000; Muñoz, Cobos, Diaz, & Aguilera, 2012).

Psyllium (eg. *Plantago psyllium L*) contains soluble fibers that are functional hydrocolloids and it is found in the plant seed of the *Plantago* genus with over 200 species distributed in temperate regions worldwide, such as India and Iran. (Guo, Cui, Wang, Goff, & Smith, 2009; Rahaie, Gharibzahedi, Razavi, & Jafari, 2012). Considered a low-cost polysaccharide source of great technological potential, it is renewable and presents biodegradability characteristics and hydro affinity that allow its application as hydrogel (Thakur & Thakur, 2014). The polysaccharides found in psyllium are constituted of xylose (74.6 %), arabinose (22.6 %), and traces of other sugars. With approximately 35% of non-reducing terminal residues, psyllium polysaccharides are highly branched constituted of β ($1 \rightarrow 4$) bonds with D-xylopyranosyl residues in the main chain (Fischer, et al., 2004).

Soaking chia seed (eg. *Salvia hispanica L*) from annual herbaceous plant belonging to the *Lamiaceae* family into water makes it exude its hard adhered mucilage (Lin, Daniel, & Whistler, 1994; Capitani, Spotorno, Nolasco, & Tomas, 2012). This mucilage have physicochemical properties responsible for its emerging as an ingredient for the production of bread, cakes, and desserts substituting fat ingredients (Borneo, Aguirre, & Leon, 2010; Capitani, Spotorno, Nolasco, & Tomas, 2012). Lin et al. (1994) describe the constitution of the fibrous content of the chia mucilage as high molecular weight polysaccharides (from 0.8 to 2.0 x 10^{-6} Da) with basic units tetrasaccharides residues, 4- O-methyl - α D-glucopyranosyl, branches with β -D- xylopyranosyl residues in the main chain, and units of ($1 \rightarrow 4$) -β -D- xylopyranosyl - ($1 \rightarrow 4$) -α -D- glucopyranosyl ($1 \rightarrow 4$) -β - D- xylopyranosyl.

Polysaccharides (gums, hydrocolloids) promote the viscosity of liquid solutions modifying or controlling their flow properties and texture; for semisolid products, they act on the deformation properties (BeMiller & Huber, 2010). The polysaccharide gel may have weak interactions, in some cases reinforced with the use of polysaccharides mixtures, called mixed gels, such as in dilute solutions of xanthan gum and locust beans, which only present significant shear stress when combined (Walstra & Vliet, 2010).

This paper is an investigation of the interaction between two emerging thickening ingredients, psyllium and chia mucilage, by applying a combined water extraction as well as the blending of different mucilage proportions.

2. Materials and methods

2.1. Materials

Psyllium husk (P) and chia seed (C) from the respectively species *Plantago psyllium L* and *Salvia hispanica L,* were obtained in a local market and sent to Cereals Technology laboratory. The husk and seed were separated stored in polyethylene bag under normal conditions of brightness and room temperature until the extraction processing. All solvents were anal

2.2. Mucilage extraction

Chia mucilage extraction was carried out based on Muñoz et al. (2012) by inserting samples of whole seeds in a beaker with distilled water 1:40 at 80°C. After a two-hour constant stirring using a screw propeller stirrer, the aqueous suspension extracted was filtered in cloth, spread on a drying tray and air-forced dried at the temperature of 50°C during 20 hours. The mucilage was subjected to hermetic storage and refrigeration (± 5°C) until the analysis. Ratio of 1:100 was established for the psyllium mucilage extraction based on Ahmadi et al. (2012), using distilled water at 80°C during one-hour stirring and subjected the aqueous suspension to a double filtering in cloth with the same drying and storage conditions employed for the chia mucilage. The third extraction consisted of a combination of the abovementioned methods. It was proceeded with the addition of 50g chia seed into 2L becker with distilled water at 80°C and after one- hour stirring, 20g of psyllium husk; the extraction continued for another hour and the aqueous suspension was subjected to double filtered in cloth. The drying and storage conditions remained were the same employed to the previous samples. Yield was measured by dividing the weight of the mucilage obtained through the initial raw material weight and multiplied by 100. Equation (1) was used to estimate the combined mucilage yield , where m_p and m_c are the weight of psyllium and chia, y_p and y_c are the yield of the isolated extraction previously carried out.

$$\text{Combined mucilage (\%)} = \frac{m_p * y_p + m_c * y_c}{m_p + m_c} \quad (1)$$

2.3. Experimental plan

This experiment was conducted with six treatments using mucilage powders of psyllium husk (P) and chia seed (C). The mixing range was: (T1) 100% P; (T2) 75% P, 25% C; (T3) 50% P, 50% C; (T4) 25% P, 75% C and (T5) 100% C. The combined mucilage was denominated T6. For a complete homogenization, each treatment was dissolved in distilled water, scattered using a mixer, and freeze-dried for 48 hours.

2.4. Reconstituted mucilage solutions

The reconstituted of frozen dried mucilage was based on the Leon-Martinez (2011) method, with modifications. A magnetic stirrer (Fisatom 7BD) was used to scatter the mucilage (room temperature, 90 min) and distilled water to prepare the 1:100 (mucilage:water rate) solutions.

2.5. Total carbohydrates content, brix and pH

The content of total carbohydrate was assessed through the phenol-sulfuric method described by Dubois et al. (1956). A refractometer Briobrix was used to determine the Brix (°Brix). The pH of the reconstituted mucilage solution was determined using potentiometric measurement at 25 °C.

2.6. Oil-holding capacity (OHC)

Oil-holding capacity was assessed based on Capitani et al. (2012) by subjecting an aliquot of 10mL of one percent reconstituted mucilage to a two-minute homogenization using a Fisatom 7BD magnetic stirrer at 5000 rpm. An oil-in-water emulsion was prepared by adding 10 mL of soybean oil under a constant three minutes stirring. The emulsion was subjected to a 30-minute centrifugation at 455xg for; subsequently, the measure of the supernatant oil volume was proceeded. Oil-holding capacity is expressed as mL oil held per mL sample.

2.7. Water solubility index (WSI)

Samples were dissolved in 30 mL of distilled water (1:100), scattered it using a magnetic stirrer (Fisatom 7BD) for five minutes at 60°C, and centrifuged at 455xg for 30 minutes (20°C). The supernatant was subjected to a six-hour drying process at 100°C and the final weight was divided by the initial weight with the result multiplied by 100 indicating the value for the water solubility index.

2.8. Thermal characteristics

TGA (Thermogravimetric analysis) and DSC (Differential Scanning Calorimetry) was performed according to Iqbal et al. (2011) using a simultaneous thermal analyzer NETZSCH STA 409 PG/PC, under nitrogen atmosphere at a flow rate of 50 cm^3 min^{-1} with 10◦C min−1 heating rate at ambient temperature range (25°C) to 600◦C using platinum crucible. TGA peak was found through differentiate TGA curve

2.9. Viscosity

A controlled stress rheometer (Brookfield DV-III, USA) with a concentric cylinder geometry (SC4-27) was used for the viscosity of the freeze dried reconstituted mucilage. The constant temperature of 25^{o}C was maintained using a water bath (Brookfield TC-502, USA).

2.10. Attenuated total reflection (ATR) spectra

ATR was employed to observe the structural modification of the samples. The spectra of the freeze dried mucilage powder were obtained using an infrared Fourier transform spectrometer (model Vertex 70v, Bruker, Germany) with platinum ATR diamond f/ vaccum. The spectral range was 400–4000 cm^{-1} with 128 scans, resolution of 4 cm^{-1}, aperture setting 6mm and acner velocity of 10Hz.

2.11. Statistical analysis

We carried out the statistical Analysis of Variance (ANOVA) followed by the Tukey test to distinguish the treatments using on RStudio software (Illinois/NCSA) with a five-percent significance level. Extraction yield, total carbohydrates content, brix, pH, oil-holding capacity, water solubility index and viscosity were carried out in triplicate.

3. Results and Discussion

3.1. Aqueous extraction

The crude yield was approximately 9.03% for dry chia seed mass, 47.4% dry psyllium husk mass, and 21.98% dry chia seed as well as dry psyllium husk mass.

The mucilage of chia seed has a strong attachment to the coat after water extraction making the separation an important factor in the yield process. Timilsenaa, Adhikarib, & Kasapisa (2016) obtained 5.6% yield by conducting an lyophilization 1:20 (seed:water ratio) of soaked seeds with swollen mucilage and mechanical separation grounding into powder passing through 200 μm sieves. Muñoz et al. (2012) obtained 6.97% with 1:40 (seed:water ratio), 8.0 pH controled extraction, ten-hour drying at 50^{O}C, and mucilage separation from the seed rubbing the dried sample over a 40-mesh screen. Studies have successfully approached the yield factors (temperature, pH, water:seed ratio) with this particular paper focusing on the separation method. The 9.03% yield was achieved through the separation using cloth and a higher seed:water ratio (1:40). The highest ratio benefited the separation through a low thickness aqueous suspension. By separating the seed before the drying procedure, we believe that extraction yield was higher considering that the procedure was conducted with the soaked seed. Felisberto et al. (2015) achieved 7.86 g /100 g of chia seeds by separating the (1:40) aqueous solution with a brush depulper and a vaccum filtering before the drying stage.

Despite the many resports on psyllium yield, only a few studies, such as Ahmadi et al. (2012), indicated 28% of filtrate dry matter for psyllium husk using hot water extraction. The method with more common application involves alkaline extractions followed by acid neutralization. No previous reports in literature are registered for the psyllium husk aqueous extraction combined the chia seed; however, equation 1 estimated a yield of 19.99%, which is numerically similar to the experimental result (21.98%). This study does not reveal any evidence of sinergic yield interaction between the raw materials during aquous extration using the studied conditions, although further experimental design studies would allow further information by using controled factors such as pH.

The pH of the reconstituted mucilage ranged from 6.33 (T1) to 6.83 (T4) and the brix from 0.75 (T1, T2, and T3) to 1.0 (T6). Oil-holding capacity ranged from 0.895 (T1) to 1.66 mL_{oil}/mL_{sample} (T3). No significant difference between the samples was observed regarding those parameters. However the carbohydrate content of T5 (13.14 g/L) was significantly different from others where the values ranged between 7.37 (T1) and 8.68 g/L (T4).

The solubilization loss was measured using the WSI (Water Solubility Index) (Figure 1). The psyllium mucilage resulted in an insolubility of 6.98% (T1) while the chia mucilage resulted in 51.26% (T5). By separating in two phases, gel and supernatant, psyllium uses most of its mucilage to form the gel chain while chia mucilage may loss the major part of it after centrifugation. The results of the blends indicated the expected behavior and the individual WSI revealed no evidence of a synergic effect of the blendings.

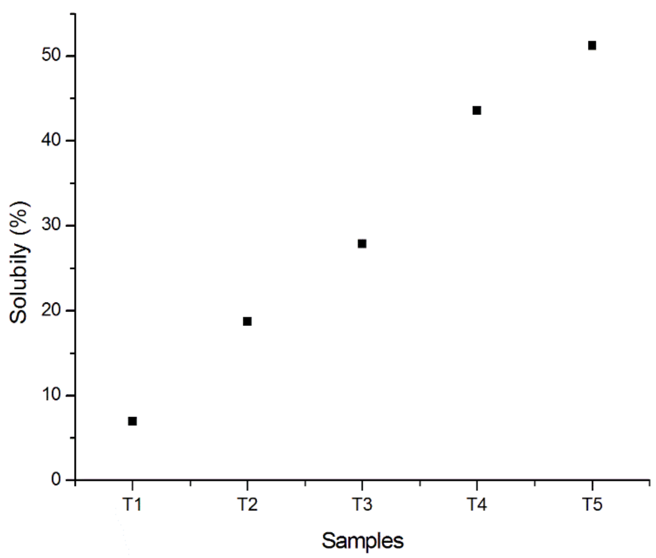


Fig. 1: Comparison of mucilage samples for the water solubility property.

Considering that the WSI chart have a linear range (R^2 = 0.9913) between the blends, this study investigates whether the combined extration has the same behavior of the blended ones using the same mucilage proportion. In order to have it revealed, we used mass balance (Figure 2) to predict the amount of chia and psyllium mucilage on the combined mucilage. Accordingly, a sample containing a mixture of 32% C and 67% P was prepared for a triplicate test. The obtained WSI was 23.18%, close to the 22.63% found for the combined mucilage leading to the conclusion that the combined fraction is consistent with the individual mix at a proportion of 32% P and 67% C (between T2 and T3).

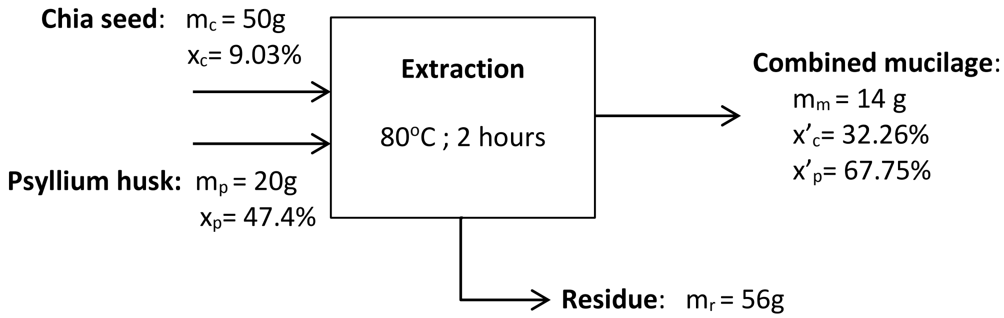


Fig.2: Mass balance of combined extraction where m_p and m_c are the weight of psyllium husk and chia seed; x_p and x_c are the percentage of mucilage of raw material; m_r is the residual weight; m_m is the mucilage weight, and x'_p and x'_c are the final fraction of each mucilage.

This results suggest that it is possible that the combined mucilage extraction have no interference on the solubilization of the individual mucilages. It is important and convinient when planning and developing a new product to consider an expected behaviour for the mixtures.

3.2. TGA and DSC

The TGA plot of the samples revealed thermal effects similar to natural hydrogels reported in a few earlier studies (Iqbal, Akbar, Saghir, Karim, & Koschella, 2011; Timilsena, Adhikari, & Kasapis, 2016). The observation of an endothermic loss had been previously reported due to the loss of absorbed moisture at a range of 50-100°C. A possible explanation for the low temperature of moisture loss is the use of platinum crucible substituting hermetical sealing.

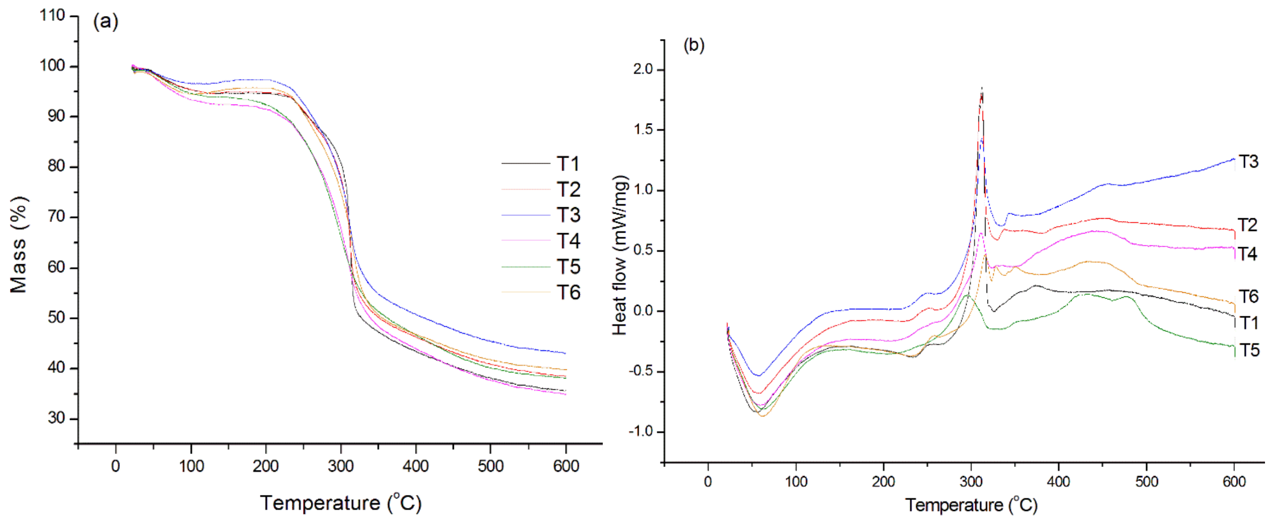


Fig. 3: (a) TGA and (b) DSC curves of mucilage samples.

The average representative weight loss was 4.94% despite the significant difference between T3 and T4 (2.33% and 7.29%, respectively) (Table 1). Two stages of decomposition were observed for all of the samples. Generally, at stage one, the initial decomposition temperature (IDT) ranged from 142 to 211°C and at stage two, the final decomposition temperature (FDT) ranged from 329 to 350°C. Stage one resulted in a 45.63% weight loss in average, with an exothermic enthalpy alteration. This stage is responsible for the major breakdown of the polymer chain forming reasonably high molecular mass volatiles. Studies have reported an IDT of 220-280°C and a FDT of 310-375°C for chia, psyllium, and natural polysaccharides mucilage (Timilsena, Adhikari, & Kasapis, 2016; Iqbal, Akbar, Saghir, Karim, & Koschella, 2011; Iqbal, Akbar, Hussain, Saghir, & Sherd, 2011). Chia mucilage results indicate better stability with the lowest weight loss of 41.33% and T6 with the major breakdown occurring at the highest temperature. The TGA peak previously observed in T4 was followed by the highest dehydration value. This study suggests that the amount of water in the polysaccharide chain could be responsible for the weakness of the main structure for exposing more boundaries compared to the others. The second decomposition stage was characterized by a decreasing curve up to the final temperature of 600°C and a mean final weight of 10.75%. The char yield average was 38.68%.

Table 1. TGA results of the mucilage samples.

Sample	Dehydration (%)	Stage 1 (°C)	TGA Peak* (°C)	Weight loss (%)	Stage 2 (°C)	Weight loss (%)	Char yield (%)
T1	4.82	207-329	313.00	49.51	329-600	9.55	36.12
T2	4.78	207-330	312.67	46.44	330-600	9.83	38.95
T3	2.33	206-330	310.54	44.27	330-600	9.60	43.80
T4	7.29	165-330	302.04	44.55	330-600	12.89	35.27
T5	5.29	142-340	313.20	41.33	340-600	14.65	38.73
T6	5.14	211-350	315.17	47.66	350-600	8.00	39.20

*TGA peak was obtained by differentiate TGA curve.

Despite of the fact that psyllium and chia mucilage have thermal characteristics of hydrogels, it was possible to differentiate these materials by the degradation behavior on stage 1 and 2. Chia mucilage required more specific heat to keep the breakdown after stage 1 by the exothermic peaks observed. In addition, chia had the lowest weight loss (41.33%) at stage 1 followed by 14.65% loss over 340°C showing that this mucilage have higher thermal stability compared to psyllium mucilage.

3.3. Viscosity

As a characteristic of non-Newtonian fluids, viscosity presented variations according to the shear rate applied (Fig 4). All of the treatments had mucilage indicating shear thinning properties, attributed to the presence of high molecular weight materials; therefore, the apparent viscosity indicated a pseudoplastic behavior (F.M. León-Martínez, 2010).

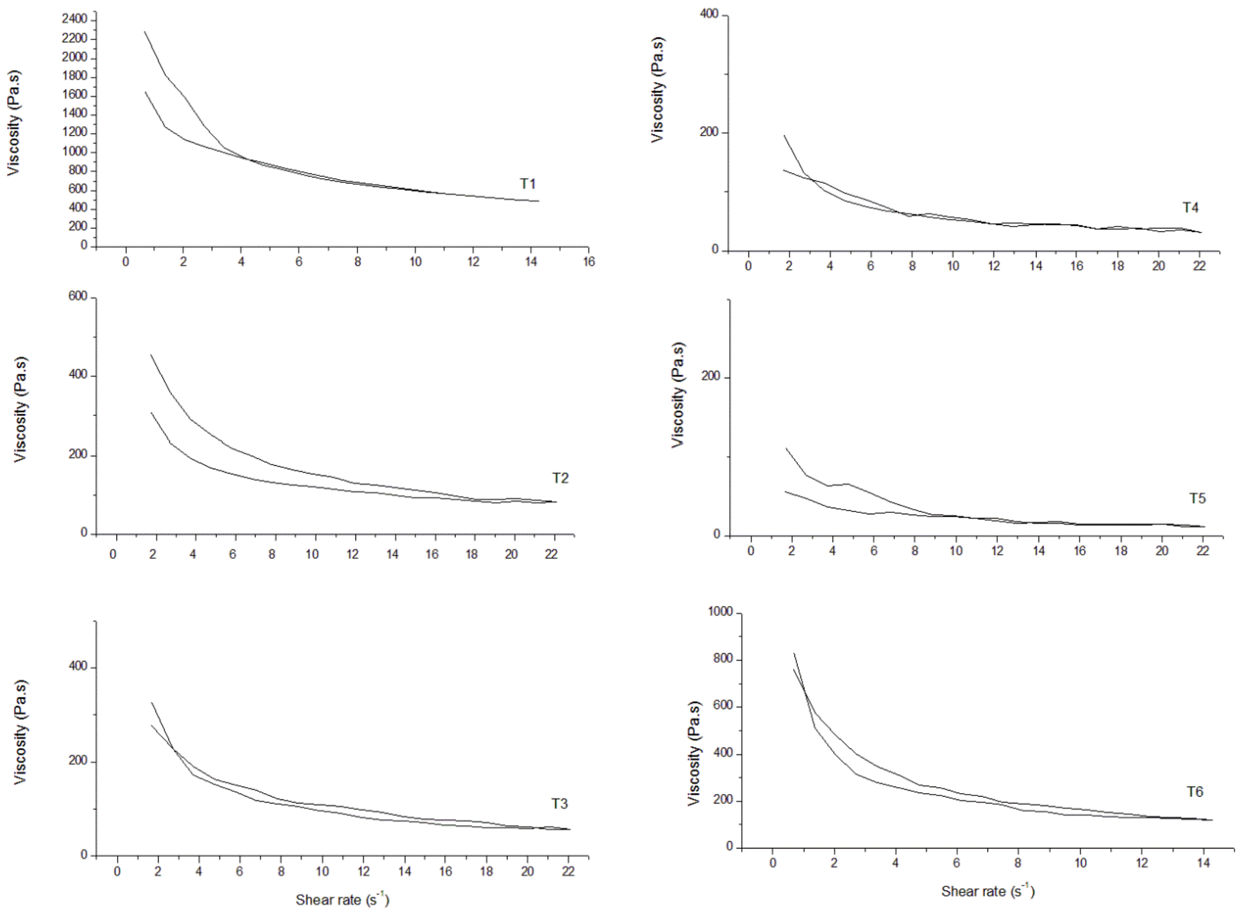


Fig. 4: Viscosity curves of mucilage samples.

The figure 5 exhibits and compare three shear rate points ($2.72s^{-1}$, $7.82s^{-1}$ and $14.96s^{-1}$) of the viscosity curve. At 2.72 s^{-1}, the viscosity has a downward trend once the chia mucilage concentration is raised (T1= 285.86, T2= 360.27, T3= 228.47, T4= 123.02, T5= 46.87 Pa.s). This fact is also exhibited to 7.82 s^{-1} and 14.96 s^{-1} shear rates, which may be regarded as an advantage since embodying of psyllium into food eventually have restrictions regarding their gelling power. Beyond that, T6 presented unexpected behaviour revealing the highest value of the blends (401.28 Pa.s). According to mass balance, the expected results were meant to be between T2 and T3. This is an indication that the aquous combined extration acts differently than a simple mucilage mixing.

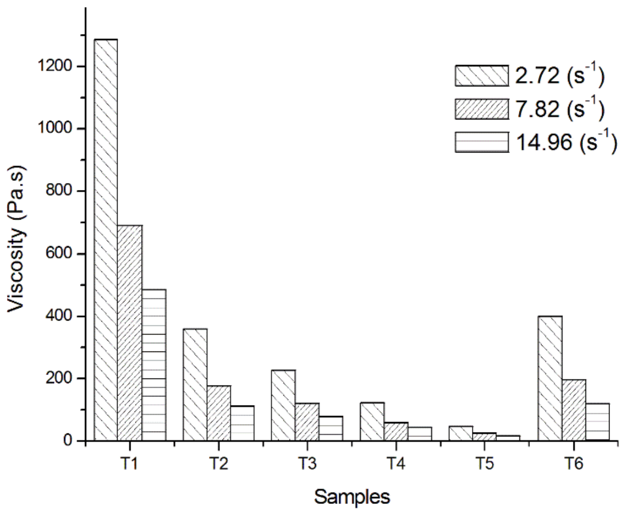


Fig. 5: Viscosity comparison of mucilage samples of three different shear rates.

3.4. ATR

Figure 6 illustrates the ATR spectra of the samples. Previous studies had obtained similar spectra for psyllium and chia mucilage. By comparing the samples, we observe that the similar broad bands ranged between 3358 to 3307 cm^{-1}, representing the hydroxyl (-OH) stretching of the gross carbohydrates; 2928 to 2886 cm^{-1}, the C-H stretching of the aromatic rings and the methyl group (CH_3); 1724 to 1726 cm^{-1}, the C=H stretching vibration of carboxylic acid; 1598 and 1420 cm^{-1}, and the symmetric stretching of carboxyl group ($-COO^-$) ion present in uronic acids. The bands at 1750 cm^{-1} and 1155 cm^{-1} may represent the bending vibration of C=O and C-O-C of the pyranose ring. At 1038 cm^{-1} can be related to C-O-C stretching of 1→4 glycosidic bonds and C-O-H bending, considered a characteristic of polysaccharide compounds. The band at 844 cm^{-1} may represent the β-nanomeric C-H deformation and glycosidic linkages attributed to glucopyranose and xylopyranose units (Cerqueira, et al. (2011), Togrul & Arslan (2003), Timilsenaa, Adhikarib, & Kasapisa (2016)). The difference between the samples occurred at the 700 range, representing cis C-H out-of-plane bends, at 1250 cm^{-1} (C-O- stretching), 1377 cm^{-1} ($-CH_3$ symmetric bend), 821 cm^{-1} (C-O out-of-plane bend) and 1653 cm^{-1} (>N-H of secondary amine) (Timilsena Y. W., 2016; Coates, 2000; Tipson, 1968).

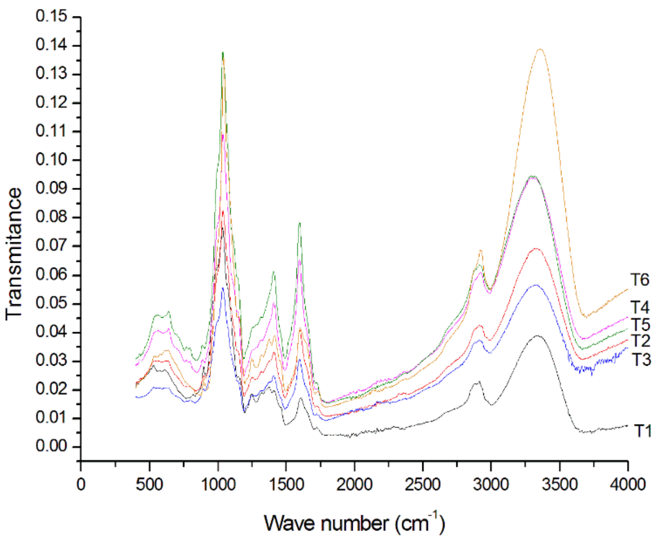


Fig. 6. ATR spectra of the mucilage samples

In general, sample bands in certain regions emerge or become more visible with the addition of the different mucilage. For example, the bands of 770 cm^{-1} and 795 cm^{-1}, where T5 and T4 present peaks, T3 and T2 have a subtle increase and T1 revealed no evidence of a peak. Sample T6 did not present the same tendency of the mixtures having indicated a similar behavior to the psyllium mucilage (T1) in some regions. In addition to not having the above-mentioned peak (770 cm^{-1} and

795 cm^{-1}), the similarity between samples T1 and T6 appear in peaks at 1248 and 1377 cm^{-1}. The remaining samples (T2 and T3) revealed only one increase soften with the increases in the chia mucilage concentration (T4 and T5). Differences between T1 and T6 molecules were found in bands 638 cm^{-1}, 821 cm^{-1} and 1653 cm^{-1}. Assuming that the molecular structure, among other factors, influences the properties of a polymeric gel, the ATR spectra may explain the T6 viscosity behavior above expectation since its conformation is similar to T1 (highest viscosity values).

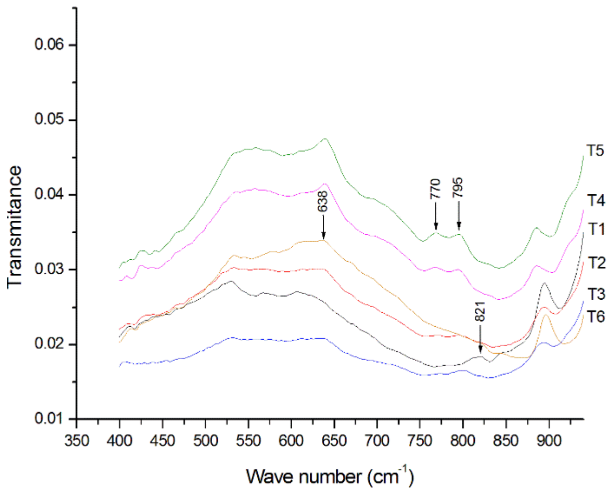


Fig. 7. ATR spectra of the region 1 (from 400 to 940cm^{-1})

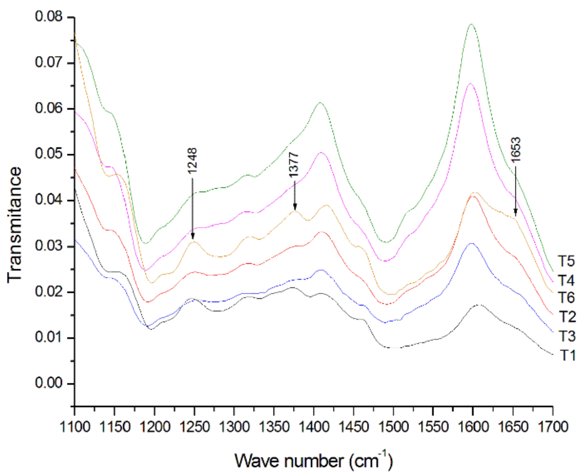


Fig. 8. ATR spectra of the region 2 (from 1100 to 1700cm^{-1})

4. Conclusion

It is important for the industry to understand the interactions among ingredients in order to achieve optimum production or even develop a new product. This study revealed that mixing chia and psyllium mucilage results in a different behaviour when compared to the combined extraction since the viscosity results were higher than expected. For this reason, the combined mucilage is the highlight of the work. As the industry seeks to leverage factors, such as thickening and the absence of artificial ingredients addition, combined extraction processes may constitute an interesting alternative. The ATR spectra was an important instrument to investigate the causes of the increased viscosity for revealing on a molecular level the similarities of the highest viscosity samples structures.

Acknowledgements

The authors are thankful to the Brazilian agencies CAPES, CNPq, and Fundação Araucária for their financial support of this work.

References

Ahmadi, R., Kalbasi-Ashtari, A., Oromiehie, A., & Yarmand, M. J. (2012). Development and characterization of a novel biodegradable edible film obtained from psyllium seed (Plantago ovata Forsk). *Journal of Food Engineering, 109* , 745-751. doi:10.1016/j.jfoodeng.2011.11.010

BeMiller, J., & Huber, K. (2010). Carboidratos. In S. Damodaran, L. Parkin, & O. Fennema, *Química de Alimentos* (pp. 76-129). Porto Alegre, Brasil: Artmed.

Borneo, R., Aguirre, A., & Leon, A. (2010). Chia (Salvia hispanica L) gel can be used as egg or oil replacer in cake formulations. *Journal of the American Dietetic Association*, 946-949. doi:10.1016/j.jada.2010.03.011

Campos, B., Ruivo, T., Scapim, M., Madrona, G., & Bergamasco, R. (2016). Optimization of the mucilage extraction process from chia seeds and application in ice cream as a stabilizer and emulsifier. *LWT - Food Science and Technology*, 874-883. doi:http://dx.doi.org/10.1016/j.lwt.2015.09.021

Capitani, M., Spotorno, V., Nolasco, S., & Tomas, M. (2012). Physicochemical and functional characterization of by-products from chia (Salvia hispanica L.) seeds of Argentina. *LWT - Food Science and Technology, 45*, 94-102. doi:10.1016/j.lwt.2011.07.012

Cerqueira, M. A. (2011). Structural and thermal characterization ofgalactomannans from non-conventional sources. *Carbohydrate Polymers*, 179–185. doi:10.1016/j.carbpol.2010.07.036

Coates, J. (2000). Interpretation of ifrared spectra: A practical aproach. In R. Meyers, *Encyclopedia of analytical chemistry* (pp. 10815-10837). Chichester: John Wiley & Sons LTD. doi:10.1002/9780470027318.a5606

Felisberto, M., Wahanik, A., Gomes-Ruffi, C., Clerici, M., Chang, Y., & Steel, C. (2015). Use of chia (Salvia hispanica L.) mucilage gel to reduce fat in pound cakes. *LWT - Food Science and Technology*, 1-7. doi:http://dx.doi.org/10.1016/j.lwt.2015.03.114

Fischer, M., Yu, N., Gray, G., Ralph, J., Anderson, L., & Marletta, J. (2004). The gel-forming polysaccharide of psyllium husk (Plantago ovata Forsk). *Carbohydrate Research*(339), 2009-2017. doi:10.1016/j.carres.2004.05.023

Gharibzahedi, S., Razavi, S., & Mousavi, S. (2013). Psyllium husk gum: An attractive carbohydrate biopolymer for the production of stable canthaxantin emulsions. *Carbohydrate Polymers*(92), 2002-2011. doi:10.1016/j.carbpol.2012.11.083

Gils, P., Ray, D., & Sahoo, P. (2009). Characteristics of xanthan gum-based biodegradable superporous hydrogel. *International Journal of Biological Macromolecules*, 364–371. doi:10.1016/j.ijbiomac.2009.07.007

Guo, Q., Cui, S. W., Wang, Q., Goff, H. D., & Smith, A. (2009). Microstructure and rheological properties of psyllium polysaccharide gel. *Food Hydrocolloids*, 1542–1547. doi:10.1016/j.foodhyd.2008.10.012

Houben, A., Hochstotter, A., & Becker, T. (2012). Possibilities to increase the quality in gluten-free bread production: an overview. *European Food Research and Technology, v. 235*, 195-208. doi:10.1007/s00217-012-1720-0

Iqbal, M., Akbar, J., Hussain, M., Saghir, S., & Sherd, M. (2011). Evaluation of hot-water extracted arabinoxylans from ispaghula seeds as drug carriers. *Carbohydrate Polymers*, 1218–1225. doi:10.1016/j.carbpol.2010.09.024

Iqbal, M., Akbar, J., Saghir, S., Karim, A., & Koschella, A. (2011). Thermal studies of plant carbohydrate polymer hydrogels. *Carbohydrate Polymers*, 1775– 1783. doi:10.1016/j.carbpol.2011.07.020

Ladjevardi, S., Gharibzahedi, S., & Mousavi, M. (2015). Development of a stable low-fat yogurt gel using functionality of psyllium (Plantago ovata Forsk) husk gum. *Carbohydrate Polymers*(125), 272-280. doi:10.1016/j.carbpol.2015.02.051

León-Martínez, F. R.-R.-T. (2011). Effects of drying conditions on the rheological properties of reconstituted. *Carbohydrate Polymers, 84*, 439–445. doi:10.1016/j.carbpol.2010.12.004

Lin, K.-Y., Daniel, J., & Whistler, R. (1994). Structure of chia seed polysaccharide. *Carbohydrate Polymers, 23*, 13-18. doi:10.1016/0144-8617(94)90085-X

Muñoz, L., Cobos, A., Diaz, O., & Aguilera, J. (2012). Chia seeds: Microstruture, mucilage extraction and hydration. *Journal of Food Engineering*, 216-224. doi:10.1016/j.jfoodeng.2011.06.037

Phillips, G., & Williams, P. (2000). *Introduction to food hydrocolloids. In: Phillips, G.O., Williamns, PA. (Eds), Handbook of Hydrocolloids.* Cambridge, England: Woodhead Publishing Limited.

Rahaie, S., Gharibzahedi, S., Razavi, S., & Jafari, S. (2012). Recent developments on new formulations based on nutrient-dense ingredients for the production of healthy-functional bread: a review. *Journal of Food Science and Technology, 51*, 2896-2906. doi:10.1007/s13197-012-0833-6

Raymundo, A., Fradinho, P., & Nunes, M. (2014). Effect of Psyllium fibre content on the textural and rheological characteristics of biscuit and biscuit dough. *1*(3), 96-105. doi:10.1016/j.bcdf.2014.03.001

Sagis, L., & Scholten, E. (2014). Complex interfaces in food: Structure and mechanical properties. *Trends in Food Science & Tecnology, 37*, 59-71. doi:10.1016/j.tifs.2014.02.009

Schramm, G. (2000). *A Practical Approach to Rheology and Rheometry* (2 ed.). Karlsruhe: Gebrueder HAAKE GmbH.

Thakur, V., & Thakur, M. (2014). Recent trends in hydrogels based on psyllium polysaccharide: a review. *Journal of Cleaner Production*(82), 1-15. doi:10.1016/j.jclepro.2014.06.066

Timilsena, Y. P., Adhikari, R., & Kasapis, S. A. (2016). Molecular and functional characteristics of purified gum from Australian chia seeds. *Carbohydrate Polymers*, 126-136. doi:10.1016/j.carbpol.2015.09.035

Timilsena, Y. W. (2016). Preparation and characterization of chia seed protein isolate–chia seed gum complex coacervates. *Food Hydrocolloids*, 554–563. doi:10.1016/j.foodhyd.2015.07.033

Tipson, R. (1968). *Infrared spectroscopy of carbohydrates: A review of the literature.* Washington, D.C.: National bureau of standards.

Togrul, H. A. (2003). Flow properties of sugar beet pulp cellulose andintrinsic viscosity–molecular weight relationship. *Carbohydrate Polymers, 54*, 63–71. doi:10.1016/S0144-8617(03)00146-2

Vazquez-Ovand, A., Rosado-Rubio, G., Chel-Guerrero, L., & Betancur-Ancona, D. (2009). Physical properties of a fibrious fraction from chia (Salvia hispanica L.). *LTW-Food Science Technology, 42*, 168-173. doi:10.1016/j.lwt.2008.05.012

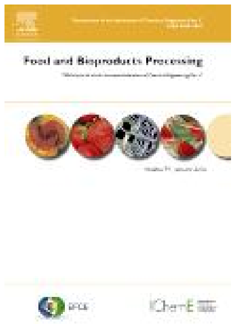
Walstra, P., & Vliet, T. (2010). Sistemas Dispersos: Considerações Básicas. Em S. Damodaran, K. Parkin, & O. Fennema, *Química de Alimentos Fennema* (pp. 611-658). Porto Alegre, Brasil: Artmed.

FOOD AND BIOPRODUCTS PROCESSING

Publication of the Institution of Chemical Engineers

AUTHOR INFORMATION PACK

TABLE OF CONTENTS



ISSN: 0960-3085

DESCRIPTION

FBP aims to be the principal international journal for publication of high quality, original papers in the branches of **engineering** and **science** dedicated to the **safe processing** of **biological products**. It is the only journal to exploit the synergy between **biotechnology**, **bioprocessing** and **food engineering**.

Papers showing how research results can be used in engineering design, and accounts of experimental or theoretical research work bringing new perspectives to established principles, highlighting unsolved problems or indicating directions for future research, are particularly welcome. Contributions that deal with new developments in equipment or processes and that can be given quantitative expression are encouraged. The journal is especially interested in papers that extend the boundaries of **food** and **bioproducts processing**.

The journal has a strong emphasis on the interface between engineering and food or bioproducts. Papers that are not likely to be published are those:

• Primarily concerned with food formulation
• That use experimental design techniques to obtain response surfaces but gain little insight from them
• That are empirical and ignore established mechanistic models, e.g., empirical drying curves
• That are primarily concerned about sensory evaluation and colour
• Concern the extraction and/or antioxidant activity of a specific biological material without providing insight that could be applied to a similar but different material,
• Containing only chemical analyses of biological materials.

The journal publishes regular special issues focusing on specific topics

Core topic areas:

Biotechnology and **bioprocessing**

• Biocatalysis and biotransformations
• Bioprocess modelling and optimisation
• Bioseparation
• Fermentation and cell culture
• Bioreactor design, instrumentation and control
• Microbial physiology and engineering metabolic
• Production formulation
• Sterile processing
• Systems biology and biological engineering
• Nanobiotechnology

Food and **drink process engineering**

• Engineering for food safety
• Environmental issues in food manufacture
• Minimal processing techniques
• Packaging
• Plant, process and product design
• Processing and microstructure interactions
• Unit operations, process modelling and optimisation in food engineering

Hygienic manufacture and **product safety**

• Fouling and cleaning
• Good manufacturing practice
• Hazard analysis
• Heating and cooling methods, including freezing, pasteurisation and thermal sterilisation
• Hygienic design
• Non-thermal processes
• Process analytical technology (PAT)
• Regulation and validation.

IMPACT FACTOR

2014: 2.474 © Thomson Reuters Journal Citation Reports 2015

ABSTRACTING AND INDEXING

ANTE
FSTA (Food Science and Technology Abstracts)
PASCAL/INIST-CNRS
SCISEARCH
Chemical Abstracts Service
Scopus
Foodline: Food Science and Technology

EDITORIAL BOARD

GUIDE FOR AUTHORS

Your Paper Your Way

We now differentiate between the requirements for new and revised submissions. You may choose to submit your manuscript as a single Word or PDF file to be used in the refereeing process. Only when your paper is at the revision stage, will you be requested to put your paper in to a 'correct format' for acceptance and provide the items required for the publication of your article.

To find out more, please visit the Preparation section below.

INTRODUCTION

All contributions must conform to the Aims and Scope of the Journal, available on the Journal homepage at http://www.elsevier.com/locate/fbp. The Institution of Chemical Engineers (IChemE) publishes only papers of the highest quality. *Papers should be original and report a noteworthy advance in understanding of the topic presented. Papers in which the main contribution to knowledge is the presentation of experimental data and the fitting of the data to established models are unlikely to be accepted* To help maintain this standard, all papers submitted are sent to referees familiar with the branch of chemical engineering covered. They advise as to whether the paper is acceptable or not and indicate possible ways in which, in their opinion, the paper might be improved. The Editor makes the final decision on publication in the light of this advice.

Types of Paper

In addition to full length papers, correspondence, and book reviews, the journal also welcomes:

Review Papers: A limited number of review papers are published each year, providing a critical assessment of previously published work in one of the core topics covered by the journal. In view of the substantial effort involved in producing a review paper, authors are advised to contact the relevant Editorial Board member before commencing.

Short Communications: Shorter papers dealing with new ideas and specific points such as novel research techniques, fresh analysis of existing work or interesting aspects or results of work-in-progress, will be considered for publication as short communications.

Papers that are not likely to be published are those:

• primarily concerned with food formulation
• that use design techniques to obtain response surfaces but gain little insight from them
• that are empirical and ignore established mechanistic models, e.g., empirical drying curves
• that are primarily concerned about sensory evaluation and colour
• concern the extraction and/or antioxidant activity of a specific biological material without providing insight that could be applied to a similar but different material
• containing only chemical analyses of biological materials.

BEFORE YOU BEGIN

Ethics in publishing

For information on Ethics in publishing and Ethical guidelines for journal publication see https://www.elsevier.com/publishingethics and https://www.elsevier.com/journal-authors/ethics.

Conflict of interest

All authors are requested to disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three Years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work. See also https://www.elsevier.com/conflictsofinterest. Further information and an example of a Conflict of Interest form can be found at: http://service.elsevier.com/app/answers/detail/a_id/286/supporthub/publishing.

Submission declaration and verification

Submission of an article implies that the work described has not been published previously (except in the form of an abstract or as part of a published lecture or academic thesis or as an electronic preprint, see https://www.elsevier.com/sharingpolicy), that it is not under consideration for publication elsewhere, that its publication is approved by all authors and tacitly or explicitly by the responsible authorities where the work was carried out, and that, if accepted, it will not be published elsewhere in the same form, in English or in any other language, including electronically without the written consent of the copyright-holder. To verify originality, your article may be checked by the originality detection service CrossCheck https://www.elsevier.com/editors/plagdetect.

Changes to authorship

Authors are expected to consider carefully the list and order of authors **before** submitting their manuscript and provide the definitive list of authors at the time of the original submission. Any addition, deletion or rearrangement of author names in the authorship list should be made only **before** the manuscript has been accepted and only if approved by the journal Editor. To request such a change, the Editor must receive the following from the **corresponding author**: (a) the reason for the change in author list and (b) written confirmation (e-mail, letter) from all authors that they agree with the addition, removal or rearrangement. In the case of addition or removal of authors, this includes confirmation from the author being added or removed.
Only in exceptional circumstances will the Editor consider the addition, deletion or rearrangement of authors **after** the manuscript has been accepted. While the Editor considers the request, publication of the manuscript will be suspended. If the manuscript has already been published in an online issue, any requests approved by the Editor will result in a corrigendum.

Copyright

Upon acceptance of an article, authors will be asked to complete a 'Journal Publishing Agreement' (for more information on this and copyright, see https://www.elsevier.com/copyright). An e-mail will be sent to the corresponding author confirming receipt of the manuscript together with a 'Journal Publishing Agreement' form or a link to the online version of this agreement.

Subscribers may reproduce tables of contents or prepare lists of articles including abstracts for internal circulation within their institutions. Permission of the Publisher is required for resale or distribution outside the institution and for all other derivative works, including compilations and translations (please consult https://www.elsevier.com/permissions). If excerpts from other copyrighted works are included, the author(s) must obtain written permission from the copyright owners and credit the source(s) in the article. Elsevier has preprinted forms for use by authors in these cases: please consult https://www.elsevier.com/permissions.

For open access articles: Upon acceptance of an article, authors will be asked to complete an 'Exclusive License Agreement' (for more information see https://www.elsevier.com/OAauthoragreement). Permitted third party reuse of open access articles is determined by the author's choice of user license (see https://www.elsevier.com/openaccesslicenses).

Author rights

As an author you (or your employer or institution) have certain rights to reuse your work. For more information see https://www.elsevier.com/copyright.

Role of the funding source

You are requested to identify who provided financial support for the conduct of the research and/or preparation of the article and to briefly describe the role of the sponsor(s), if any, in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication. If the funding source(s) had no such involvement then this should be stated.

Funding body agreements and policies

Elsevier has established a number of agreements with funding bodies which allow authors to comply with their funder's open access policies. Some authors may also be reimbursed for associated publication fees. To learn more about existing agreements please visit https://www.elsevier.com/fundingbodies.

Open access

This journal offers authors a choice in publishing their research:

Open access

- Articles are freely available to both subscribers and the wider public with permitted reuse
- An open access publication fee is payable by authors or on their behalf e.g. by their research funder or institution

Subscription

- Articles are made available to subscribers as well as developing countries and patient groups through our universal access programs (https://www.elsevier.com/access).
- No open access publication fee payable by authors.

Regardless of how you choose to publish your article, the journal will apply the same peer review criteria and acceptance standards.

For open access articles, permitted third party (re)use is defined by the following Creative Commons user licenses:

Creative Commons Attribution (CC BY)

Lets others distribute and copy the article, create extracts, abstracts, and other revised versions, adaptations or derivative works of or from an article (such as a translation), include in a collective work (such as an anthology), text or data mine the article, even for commercial purposes, as long as they credit the author(s), do not represent the author as endorsing their adaptation of the article, and do not modify the article in such a way as to damage the author's honor or reputation.

Creative Commons Attribution-NonCommercial-NoDerivs (CC BY-NC-ND)
For non-commercial purposes, lets others distribute and copy the article, and to include in a collective work (such as an anthology), as long as they credit the author(s) and provided they do not alter or modify the article.

The open access publication fee for this journal is **USD 3000**, excluding taxes. Learn more about Elsevier's pricing policy: http://www.elsevier.com/openaccesspricing.

Green open access

Authors can share their research in a variety of different ways and Elsevier has a number of green open access options available. We recommend authors see our green open access page for further information (http://elsevier.com/greenopenaccess). Authors can also self-archive their manuscripts immediately and enable public access from their institution's repository after an embargo period. This is the version that has been accepted for publication and which typically includes author-incorporated changes suggested during submission, peer review and in editor-author communications. Embargo period: For subscription articles, an appropriate amount of time is needed for journals to deliver value to subscribing customers before an article becomes freely available to the public. This is the embargo period and it begins from the date the article is formally published online in its final and fully citable form.

This journal has an embargo period of 24 months.

Language (usage and editing services)

Please write your text in good English (American or British usage is accepted, but not a mixture of these). Authors who feel their English language manuscript may require editing to eliminate possible grammatical or spelling errors and to conform to correct scientific English may wish to use the English Language Editing service available from Elsevier's WebShop (http://webshop.elsevier.com/languageediting/) or visit our customer support site (http://support.elsevier.com) for more information.

Submission

Our online submission system guides you stepwise through the process of entering your article details and uploading your files. The system converts your article files to a single PDF file used in the peer-review process. Editable files (e.g., Word, LaTeX) are required to typeset your article for final publication. All correspondence, including notification of the Editor's decision and requests for revision, is sent by e-mail.

Submit your article
Please submit your article via http://ees.elsevier.com/fbp.

Referees

Please submit, with the manuscript, the names, addresses and e-mail addresses of **4** potential referees. The suggested referees should not be from the same institution as the authors, and at least two referees should be from countries other than those of the authors. Note that the editor retains the sole right to decide whether or not the suggested reviewers are used.

PREPARATION

NEW SUBMISSIONS

Submission to this journal proceeds totally online and you will be guided stepwise through the creation and uploading of your files. The system automatically converts your files to a single PDF file, which is used in the peer-review process.
As part of the Your Paper Your Way service, you may choose to submit your manuscript as a single file to be used in the refereeing process. This can be a PDF file or a Word document, in any format or lay-out that can be used by referees to evaluate your manuscript. It should contain high enough quality figures for refereeing. If you prefer to do so, you may still provide

all or some of the source files at the initial submission. Please note that individual figure files larger than 10 MB must be uploaded separately.

References

There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume number/book chapter and the pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct.

Formatting requirements

There are no strict formatting requirements but all manuscripts must contain the essential elements needed to convey your manuscript, for example Abstract, Keywords, Introduction, Materials and Methods, Results, Conclusions, Artwork and Tables with Captions.
If your article includes any Videos and/or other Supplementary material, this should be included in your initial submission for peer review purposes.
Divide the article into clearly defined sections.

Figures and tables embedded in text
Please ensure the figures and the tables included in the single file are placed next to the relevant text in the manuscript, rather than at the bottom or the top of the file.

REVISED SUBMISSIONS

Use of word processing software
Regardless of the file format of the original submission, at revision you must provide us with an editable file of the entire article. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier: https://www.elsevier.com/guidepublication). See also the section on Electronic artwork.
To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

Article structure

Subdivision - numbered sections
Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

Introduction
State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

Material and methods
Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

Theory/calculation
A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis.

Results
Results should be clear and concise.

Discussion
This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Essential title page information

• ***Title.*** Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.

• ***Author names and affiliations.*** Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.

• ***Corresponding author.*** Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication. **Ensure that the e-mail address is given and that contact details are kept up to date by the corresponding author.**

• ***Present/permanent address.*** If an author has moved since the work described in the article was done, or was visiting at the time, a 'Present address' (or 'Permanent address') may be indicated as a footnote to that author's name. The address at which the author actually did the work must be retained as the main, affiliation address. Superscript Arabic numerals are used for such footnotes.

Abstract

A concise and factual abstract is required (maximum 200 words). The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.

Graphical abstract

Although a graphical abstract is optional, its use is encouraged as it draws more attention to the online article. The graphical abstract should summarize the contents of the article in a concise, pictorial form designed to capture the attention of a wide readership. Graphical abstracts should be submitted as a separate file in the online submission system. Image size: Please provide an image with a minimum of 531 × 1328 pixels (h × w) or proportionally more. The image should be readable at a size of 5 × 13 cm using a regular screen resolution of 96 dpi. Preferred file types: TIFF, EPS, PDF or MS Office files. See https://www.elsevier.com/graphicalabstracts for examples.

Authors can make use of Elsevier's Illustration and Enhancement service to ensure the best presentation of their images and in accordance with all technical requirements: Illustration Service.

Highlights

Highlights are mandatory for this journal. They consist of a short collection of bullet points that convey the core findings of the article and should be submitted in a separate editable file in the online submission system. Please use 'Highlights' in the file name and include 3 to 5 bullet points (maximum 85 characters, including spaces, per bullet point). See https://www.elsevier.com/highlights for examples.

Keywords

Immediately after the abstract, provide a maximum of 6 keywords, using British spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

Abbreviations

Define abbreviations that are not standard in this field in a footnote to be placed on the first page of the article. Such abbreviations that are unavoidable in the abstract must be defined at their first mention there, as well as in the footnote. Ensure consistency of abbreviations throughout the article.

Acknowledgements

Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

Nomenclature and units

Follow internationally accepted rules and conventions: use the international system of units (SI). If other quantities are mentioned, give their equivalent in SI. You are urged to consult IUPAC: Nomenclature of Inorganic Chemistry: http://www.iupac.org/ for further information.

Math formulae

Please submit math equations as editable text and not as images. Present simple formulae in line with normal text where possible and use the solidus (/) instead of a horizontal line for small fractional terms, e.g., X/Y. In principle, variables are to be presented in italics. Powers of e are often more conveniently denoted by exp. Number consecutively any equations that have to be displayed separately from the text (if referred to explicitly in the text).

Footnotes

Footnotes should be used sparingly. Number them consecutively throughout the article. Many word processors build footnotes into the text, and this feature may be used. Should this not be the case, indicate the position of footnotes in the text and present the footnotes themselves separately at the end of the article.

Artwork

Electronic artwork

General points

• Make sure you use uniform lettering and sizing of your original artwork.
• Preferred fonts: Arial (or Helvetica), Times New Roman (or Times), Symbol, Courier.
• Number the illustrations according to their sequence in the text.
• Use a logical naming convention for your artwork files.
• Indicate per figure if it is a single, 1.5 or 2-column fitting image.
• For Word submissions only, you may still provide figures and their captions, and tables within a single file at the revision stage.
• Please note that individual figure files larger than 10 MB must be provided in separate source files. A detailed guide on electronic artwork is available on our website: https://www.elsevier.com/artworkinstructions.

You are urged to visit this site; some excerpts from the detailed information are given here.

Formats

Regardless of the application used, when your electronic artwork is finalized, please 'save as' or convert the images to one of the following formats (note the resolution requirements for line drawings, halftones, and line/halftone combinations given below):
EPS (or PDF): Vector drawings. Embed the font or save the text as 'graphics'.
TIFF (or JPG): Color or grayscale photographs (halftones): always use a minimum of 300 dpi.
TIFF (or JPG): Bitmapped line drawings: use a minimum of 1000 dpi.
TIFF (or JPG): Combinations bitmapped line/half-tone (color or grayscale): a minimum of 500 dpi is required.

Please do not:

• Supply files that are optimized for screen use (e.g., GIF, BMP, PICT, WPG); the resolution is too low.
• Supply files that are too low in resolution.
• Submit graphics that are disproportionately large for the content.

Color artwork

Please make sure that artwork files are in an acceptable format (TIFF (or JPEG), EPS (or PDF), or MS Office files) and with the correct resolution. If, together with your accepted article, you submit usable color figures then Elsevier will ensure, at no additional charge, that these figures will appear in color online (e.g., ScienceDirect and other sites) regardless of whether or not these illustrations are reproduced in color in the printed version. **For color reproduction in print, you will receive information regarding the costs from Elsevier after receipt of your accepted article**. Please indicate your preference for color: in print or online only. For further information on the preparation of electronic artwork, please see https://www.elsevier.com/artworkinstructions.

Figure captions

Ensure that each illustration has a caption. A caption should comprise a brief title (**not** on the figure itself) and a description of the illustration. Keep text in the illustrations themselves to a minimum but explain all symbols and abbreviations used.

Tables

Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules.

The tables must be submitted separately and must appear after the figures in a manuscript.

References

Citation in text

Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Any references cited in the abstract must be given in full. Unpublished results and personal communications are not recommended in the reference list, but may be mentioned in the text. If these references are included in the reference list they should follow the standard reference style of the journal and should include a substitution of the publication date with either 'Unpublished results' or 'Personal communication'. Citation of a reference as 'in press' implies that the item has been accepted for publication.

Web references

As a minimum, the full URL should be given and the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given. Web references can be listed separately (e.g., after the reference list) under a different heading if desired, or can be included in the reference list.

Reference management software

Most Elsevier journals have their reference template available in many of the most popular reference management software products. These include all products that support Citation Style Language styles (http://citationstyles.org), such as Mendeley (http://www.mendeley.com/features/reference-manager) and Zotero (https://www.zotero.org/), as well as EndNote (http://endnote.com/downloads/styles). Using the word processor plug-ins from these products, authors only need to select the appropriate journal template when preparing their article, after which citations and bibliographies will be automatically formatted in the journal's style. If no template is yet available for this journal, please follow the format of the sample references and citations as shown in this Guide.

Users of Mendeley Desktop can easily install the reference style for this journal by clicking the following link:
http://open.mendeley.com/use-citation-style/food-and-bioproducts-processing
When preparing your manuscript, you will then be able to select this style using the Mendeley plug-ins for Microsoft Word or LibreOffice.

Reference formatting

There are no strict requirements on reference formatting at submission. References can be in any style or format as long as the style is consistent. Where applicable, author(s) name(s), journal title/book title, chapter title/article title, year of publication, volume number/book chapter and the pagination must be present. Use of DOI is highly encouraged. The reference style used by the journal will be applied to the accepted article by Elsevier at the proof stage. Note that missing data will be highlighted at proof stage for the author to correct. If you do wish to format the references yourself they should be arranged according to the following examples.

Reference style
Text: All citations in the text should refer to:
1. *Single author:* the author's name (without initials, unless there is ambiguity) and the year of publication;
2. *Two authors:* both authors' names and the year of publication;
Three or more authors: first author's name followed by 'et al.' and the year of publication. Citations may be made directly (or parenthetically). Groups of references should be listed first alphabetically, then chronologically.
Examples: 'as demonstrated (Allan, 2000a, 2000b, 1999; Allan and Jones, 1999). Kramer et al. (2010) have recently shown ....'
List: References should be arranged first alphabetically and then further sorted chronologically if necessary. More than one reference from the same author(s) in the same year must be identified by the letters 'a', 'b', 'c', etc., placed after the year of publication.
Examples:
Reference to a journal publication:
Van der Geer, J., Hanraads, J.A.J., Lupton, R.A., 2010. The art of writing a scientific article. J. Sci. Commun. 163, 51–59.
Reference to a book:
Strunk Jr., W., White, E.B., 2000. The Elements of Style, fourth ed. Longman, New York. Reference to a chapter in an edited book:
Mettam, G.R., Adams, L.B., 2009. How to prepare an electronic version of your article, in: Jones, B.S., Smith , R.Z. (Eds.), Introduction to the Electronic Age. E-Publishing Inc., New York, pp. 281–304. Reference to a website:
Cancer Research UK, 1975. Cancer statistics reports for the UK. http://www.cancerresearchuk.org/aboutcancer/statistics/cancerstatsreport/ (accessed 13.03.03).

Journal abbreviations source
Journal names should be abbreviated according to the List of Title Word Abbreviations: http://www.issn.org/services/online-services/access-to-the-ltwa/.

Video data
Elsevier accepts video material and animation sequences to support and enhance your scientific research. Authors who have video or animation files that they wish to submit with their article are strongly encouraged to include links to these within the body of the article. This can be done in the same way as a figure or table by referring to the video or animation content and noting in the body text where it should be placed. All submitted files should be properly labeled so that they directly relate to the video file's content. In order to ensure that your video or animation material is directly usable, please provide the files in one of our recommended file formats with a preferred maximum size of 150 MB. Video and animation files supplied will be published online in the electronic version of your article in Elsevier Web products, including ScienceDirect: http://www.sciencedirect.com. Please supply 'stills' with your files: you can choose any frame from the video or animation or make a separate image. These will be used instead of standard icons and will personalize the link to your video data. For more detailed instructions please visit our video instruction pages at https://www.elsevier.com/artworkinstructions. Note: since video and animation cannot be embedded in the print version of the journal, please provide text for both the electronic and the print version for the portions of the article that refer to this content.

AudioSlides
The journal encourages authors to create an AudioSlides presentation with their published article. AudioSlides are brief, webinar-style presentations that are shown next to the online article on ScienceDirect. This gives authors the opportunity to summarize their research in their own words and to help readers understand what the paper is about. More information and examples are available at https://www.elsevier.com/audioslides. Authors of this journal will automatically receive an invitation e-mail to create an AudioSlides presentation after acceptance of their paper.

Supplementary material
1. Supplementary material can support and enhance your scientific research. Supplementary files offer the author additional possibilities to publish supporting applications, high-resolution images, background datasets, sound clips and more. Please note that such items are published online exactly as they are submitted; there is no typesetting involved (supplementary data supplied as an Excel file or as a PowerPoint slide will appear as such online). Please submit the material together with the article and supply a concise and descriptive caption for each file. If you wish to make any changes to supplementary data during any stage of the process, then please make sure to provide an updated

file, and do not annotate any corrections on a previous version. Please also make sure to switch off the 'Track Changes' option in any Microsoft Office files as these will appear in the published supplementary file(s). For more detailed instructions please visit our artwork instruction pages at https://www.elsevier.com/artworkinstructions.

Interactive MATLAB Figure Viewer

This journal features the Interactive MATLAB Figure Viewer, allowing you to display figures created in MATLAB in the .FIG format in an interactive viewer next to the article. Please go to https://www.elsevier.com/matlab for more information and submission instructions.

Interactive plots

This journal enables you to show an Interactive Plot with your article by simply submitting a data file. For instructions please go to https://www.elsevier.com/interactiveplots.

Submission checklist

The following list will be useful during the final checking of an article prior to sending it to the journal for review. Please consult this Guide for Authors for further details of any item.

Ensure that the following items are present:

One author has been designated as the corresponding author with contact details:

• E-mail address
• Full postal address

All necessary files have been uploaded, and contain:

• Keywords
• All figure captions
• All tables (including title, description, footnotes)

Further considerations

• Manuscript has been 'spell-checked' and 'grammar-checked'
• All references mentioned in the Reference list are cited in the text, and vice versa
• Permission has been obtained for use of copyrighted material from other sources (including the Internet)

Printed version of figures (if applicable) in color or black-and-white

• Indicate clearly whether or not color or black-and-white in print is required.

For any further information please visit our customer support site at http://support.elsevier.com.

AFTER ACCEPTANCE

Use of the Digital Object Identifier

The Digital Object Identifier (DOI) may be used to cite and link to electronic documents. The DOI consists of a unique alpha-numeric character string which is assigned to a document by the publisher upon the initial electronic publication. The assigned DOI never changes. Therefore, it is an ideal medium for citing a document, particularly 'Articles in press' because they have not yet received their full bibliographic information. Example of a correctly given DOI (in URL format; here an article in the journal *Physics Letters B*):
http://dx.doi.org/10.1016/j.physletb.2010.09.059

When you use a DOI to create links to documents on the web, the DOIs are guaranteed never to change.

Proofs

One set of page proofs (as PDF files) will be sent by e-mail to the corresponding author (if we do not have an e-mail address then paper proofs will be sent by post) or, a link will be provided in the e-mail so that authors can download the files themselves. Elsevier now provides authors with PDF proofs which can be annotated; for this you will need to download Adobe Reader version 9 (or higher) available free from http://get.adobe.com/reader. Instructions on how to annotate PDF files will accompany the proofs (also given online). The exact system requirements are given at the Adobe site: http://www.adobe.com/products/reader/tech-specs.html.
If you do not wish to use the PDF annotations function, you may list the corrections (including replies to the Query Form) and return them to Elsevier in an e-mail. Please list your corrections quoting line number. If, for any reason, this is not possible, then mark the corrections and any other comments (including replies to the Query Form) on a printout of your proof and scan the pages and return via e-mail. Please use this proof only for checking the typesetting, editing, completeness and correctness of the text, tables and figures. Significant changes to the article as accepted for publication will only be considered at this stage with permission from the Editor. We will do everything possible to get your article published quickly

and accurately. It is important to ensure that all corrections are sent back to us in one communication: please check carefully before replying, as inclusion of any subsequent corrections cannot be guaranteed. Proofreading is solely your responsibility.

Offprints

The corresponding author, at no cost, will be provided with a personalized link providing 50 days free access to the final published version of the article on ScienceDirect. This link can also be used for sharing via email and social networks. For an extra charge, paper offprints can be ordered via the offprint order form which is sent once the article is accepted for publication. Both corresponding and co-authors may order offprints at any time via Elsevier's WebShop (http://webshop.elsevier.com/myarticleservices/offprints). Authors requiring printed copies of multiple articles may use Elsevier WebShop's 'Create Your Own Book' service to collate multiple articles within a single cover (http://webshop.elsevier.com/myarticleservices/booklets).

AUTHOR INQUIRIES

You can track your submitted article at https://www.elsevier.com/track-submission. You can track your accepted article at https://www.elsevier.com/trackarticle. You are also welcome to contact Customer Support via http://support.elsevier.com.