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Original article

Optimisation study of gum extraction from Basil seeds (*Ocimum basilicum* L.)

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Summary Basil seed (*Ocimum basilicum* L.) is cultivated in large quantities in different regions of Iran. This seed has reasonable amounts of gum with good functional properties which is comparable with commercial food hydrocolloids. A central composite rotatable design was applied to evaluate the effects of temperature, pH and water/seed ratio on the yield, apparent viscosity and protein content of water-extracted Basil seed gum. All of the variables significantly ($P < 0.05$) affected the extraction yield, whereas the effect of water/seed ratio on apparent viscosity and the effects of pH and water/seed ratio on protein content were not significant ($P > 0.05$). Numerical optimisation determined the optimum extraction conditions based on the highest yield and viscosity and the lowest protein content as being temperature 68.71 °C, pH 8.09 and water/seed ratio 65.98:1. Power law model well described non-Newtonian pseudoplastic behaviour of BSG. Flow behaviour index (n) and consistency index (K) of 1% crude and pure BSG samples were 0.306, 0.283 and 17.46, 20.22 Pa s^n, respectively.

Keywords Apparent viscosity, Basil seed gum, extraction, rheology, response surface methodology.

Introduction

Basil (*Ocimum basilicum* L.) is a member of genus *Ocimum*. The genus *Ocimum* comprises between 50 and 150 species of herbs and shrubs. Distributed worldwide it is found in the tropical regions of Asia, Africa and Central and South America (Paton *et al*., 1999; Simon *et al*., 1999). Basil is one of the endemic plants in Iran that is produced and used as a pharmaceutical plant in high quantity. Besides its use in traditional medicine, it is widely used as a culinary herb and it is a well-known source of flavouring principles (Naghibi *et al*., 2005). Essential oil extracted from *O. basilicum* L. has antioxidative, antimicrobial activity (Javanmardi *et al*., 2003). Mathews *et al*. (1993) have reported the physical characteristics and chemical composition of Indian basil seeds. Physico-mechanical properties of the Iranian basil seeds have been recently reported by Razavi *et al*. (2008). The outer pericarp (or outer epidermis) of basil seeds, when soaked in water, soon swells into a gelatinous mass (Azoma & Sakamoto, 2003). In early studies (Anjaneyalu & Tharanathan, 1972; Tharanathan & Anjaneyalu, 1974, 1975; Anjaneyalu & Channe Gowda, 1979) the polysaccharides extracted from basil seed by cold water extraction and alcohol precipitation, have been reported to have two major fractions: (i) an acid-stable core glucomannan (43%) having a ratio of glucose to mannose 10:2, and (ii) a $(1 \rightarrow 4)$-linked xylan (24.29%) having acidic side chains at C-2 and C-3 of the xylosyl residues in acid-soluble portion. Also, a minor fraction of glucan (2.31%) as a degraded cellulose material with DP = 80 has been reported.

There are many reports about investigating the effect of the different extraction conditions on the extracted gum from different sources (e.g. Balke & Diosady, 2000; Somboonpanyakul *et al*., 2006; Milani *et al*., 2007) and some of them have used response surface methodology (RSM) to determine the optimum conditions (Cui *et al*., 1994; Maherani *et al*., 2007; Pereira-Pacheco *et al*., 2007). There is no published study for optimising the gum extraction from basil seed. *Ocimum* genus is characterised by a great variability in its morphology and chemotypes (Suppakul *et al*., 2003). There are

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several chemotypes of basil seed cultivated in various region and different climates of Iran. Therefore, variability on the quantities of the extracted gum is expected. Furthermore, there is a great potential to cultivate basil seed for gum extraction in Iran. The aim of this research was to study the different factors affecting the extracted gum from basil seeds found locally in Iran, in terms of extraction yield, apparent viscosity, protein content and identifying the optimum conditions for the gum extraction by RSM and the least squares technique. Furthermore, rheological parameters of both crude and pure basil seed gum (BSG) were measured and compared with other food hydrocolloids.

Materials and methods

Basil seed preparation and analysis

Six different basil seeds were purchased from some cities of Iran (Qom, Kerman, Khoram Abad, Isfahan, Mashhad and Yazd). The basil seeds were carefully cleaned removing dusts, stones and chaffs. The cleaned seeds were then packed in plastic bags, sealed and preserved in a dry and cool place until the gum extraction step. The moisture, ash and protein content of the basil seeds were analysed according to the approved AACC methods 44-01, 08-01 and 46-10 (American Association of Cereal Chemist (AACC), 1995), respectively. The lipid content of the samples was measured as previously described (Anjaneyalu & Tharanathan, 1971). Carbohydrate values were obtained by difference.

Gum extraction procedure

Selection of the best basil seed samples was carried out based on the highest extraction yield and the apparent viscosity. The gum extraction conditions were as follows: 50 °C temperature, pH 7, 20 min soaking time and a water/seed ratio of 50:1. A soaking time of 20 min was selected based on preliminary trials which this soaking time was led to the highest extraction yield. After selecting the best seed, for further studies the optimal gum extraction conditions were determined by varying the following factors: temperatures (25–85 °C), pH (4–10) and water/seed ratio (50:1–80:1). Aqueous gum extraction was carried out as follows: Distilled water was adjusted at different pH 4, 5.22, 7, 8.78 and 10 by addition of hydrochloric acid or sodium hydroxide solutions. For each pH, the water was warmed up at different temperatures: 25, 37.11, 55, 72.86 and 85 °C. The seeds were rinsed with given volume of water in a short time and mixed with water (in a given ratio of water/seed) at a specific pH and temperature and enough time was given to reach the stage where the seeds were completely swelled (20 min agitation, 1000 rpm). Gum separation from the swelled seeds was done by passing the seeds through an extractor (Pars Khazar 700P, Rasht, Iran) with a rotating rough plate that scraped the gum layer on the seed surface. The separated gum was collected and the residual gums adhered to the seeds was subjected to immersion in water and the rotating extractor. This procedure was done four times. The collected gum from the different stages was mixed, filtered (by a cheese cloth) and dried by vacuum oven at 50 °C. Finally, the dried extracted gums were then ground and packed in the plastic bags and stored under dry and cool conditions.

Purification of extracted BSG

Before optimisation step, effect of partial purification of crude BSG by alcoholic precipitation was studied based on the extraction yield, the apparent viscosity, the protein and ash content. With this purpose, after filtration of the crude extract, three volumes of 95% ethyl alcohol were added to one volume of the extracted gum and left overnight at 4 °C. The precipitate was then recovered using a sieve to allow excess solvent to drain. The final precipitate was dispersed in distilled water with continuous stirring (30 min) and then dried at 50 °C with vacuum dryer. The dried gum was then ground and used for analysis.

Evaluation of extracted gum

Extraction yield

The yield of the extracted gum for different basil seeds and various extraction conditions was determined by weighing the dried extracted gums and calculating wet basis:

$$Y = 100 \times \left(\frac{\text{mass of extracted gum}(g)}{\text{mass of basil seed}(g)}\right)$$

Rheological measurements

Samples were prepared by dispersing the gum powder in deionised water using a blender for 15 min at room temperature followed by dispersion under heating at 80 °C for 10 min in a water bath. Finally, the dispersions were homogenised at a low speed in a blender for 5 min, and cooled down to 25 °C. All sample dispersions were prepared in duplicate. Flow behaviour and apparent viscosity of gum dispersions were measured using a rotational viscometer (Bohlin Model Visco 88; Bohlin Instruments, Worcestershire, UK) equipped with a heating circulator (Julabo, Model F12-MC; Julabo Labortechnik, GmbH D-77960, Seelbach, Germany). According to the viscosity of dispersions, appropriate measuring spindles (C14, C25 and C30) were selected during viscosity measurements. Prepared samples were loaded into the cup and allowed to equilibrate for

15 min at room temperature (25 °C) before subjecting to a logarithmic shear rate ramp between '0 and 300 s^{-1}' during 3 min. The values of consistency index (K) and flow behaviour index (n) were measured using the power law model:

$$\tau = K\dot{\gamma}^n \quad (1)$$

where τ is the shear stress (Pa), $\dot{\gamma}$ is the shear rate (1/s), n is the flow behaviour index (dimensionless) and K is the consistency index (Pa s^n). Apparent viscosities of BSG for the RSM study were measured for the 0.8% samples at temperature of 25 °C and shear rate of 98.9 s^{-1}. Flow behaviour studies were done with 1% samples of crude and pure BSG.

Protein content

The protein content of extracted gums was determined as an impurity index (Cui *et al.*, 1994) according to the approved AACC method 46-10 (American Association of Cereal Chemist (AACC), 1995), as used for seed analysis. For some purified samples of extracted gum, additional analysis of lipid, ash and moisture were done as described in Basil seed analysis section.

Experimental design and statistical analysis

A central composite rotatable design (CCRD) with three variables was followed to examine the response pattern and also to determine the optimum synergy of variables (Cochran & Cox, 1957). The factors and their optimised ranges were chosen for independent variables were extraction temperature (25–85 °C), pH (4–10) and water/seed ratio (50:1–80:1), each variable at five levels, namely, −1.68, −1, 0, 1 and 1.68. The range of three independent variables was based on the results of preliminary experiments. The parameters measured as dependent variables were the extraction yield, the apparent viscosity and the protein content. The CCRD in the experimental design consists of eight factorial points, six axial points and six replicates of the central point. Six replicates at the centre of the design were used to estimate the error sum of squares. Experiments were randomised to minimise the effects of unexplained variability in the observed responses due to extraneous factors. The CCRD and responses of dependent variables for gum extraction from the basil seeds are shown in Table S1. Although the exact mathematical model for any response (dependent variables) usually is unknown, it can be estimated accurately by a second-order polynomial expression that accounts for variations caused by linear and quadratic order effects as well as by interaction (Cochran & Cox, 1957; Floros & Chinnan, 1988; Mudahar *et al.*, 1990; Hu, 1999). The data were analysed using the Design-Expert Software (Version 6.0.2®, 2000, Stat-Ease, Inc., Minneapolis, MN, USA) to fit the following polynomial equation:

$$Y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \sum \beta_{ij} x_i x_j \quad (2)$$

where Y is the dependent variable (extraction yield, apparent viscosity and protein content); β_0 is constant; β_i, β_{ii} and β_{ij} are regression coefficients; and x_i and x_j are levels of the independent variables. To visualise the relationship between the response and the experimental levels of each factor, the fitted polynomial regression equations were expressed graphically using the Design-Expert Software. Equation 2 was fit to the experimental data (Table S1) and three models were obtained for the responses. The adequacy and fitness of these models was tested by analysis of variance (ANOVA). Adequacy of regression models were evaluated by determination of R^2, adjusted R^2, predicted R^2 and absolute average deviation (AAD). The AAD was calculated by the following equation (Baş & Boyacı, 2007):

$$\mathrm{AAD} = \left\{ \left[\sum_{i=1}^{p} \left(\left| y_{i,\mathrm{exp}} - y_{i,\mathrm{cal}} \right| / y_{i,\mathrm{exp}} \right) \right] / p \right\} \times 100 \quad (3)$$

where $y_{i,\mathrm{exp}}$ and $y_{i,\mathrm{cal}}$ are the experimental and calculated responses, respectively, and p is the number of the experimental run. When the optimum conditions of gum extraction were determined by the models derived using RSM, BSG extraction was carried out under these conditions. To verify the adequacy of the models, experimental data were compared to the values predicted by regression models.

Results and discussion

Selection of the best basil seed for gum extraction

There was a significant difference ($P < 0.01$) between the values of extraction yield and apparent viscosity of the six Iranian basil seeds. The highest (15.42% yield and 429 mPa s viscosity) and the lowest (11.46% yield and 318 mPa s viscosity) values were related to Isfahan and Khoram Abad basil seeds, respectively. In this study, the basil seeds from Isfahan region were used to study the effect of partial purification of crude BSG and to find the optimum conditions in BSG extraction.

Chemical composition of basil seeds and crude BSG

The chemical composition of all the different basil seeds collected for this study is presented in Table 1. These results showed that composition of basil seeds from Iran were statistically ($P < 0.05$) different from the Indian basil seeds reported by Mathews *et al.* (1993). The most important difference was related to the protein, lipid and carbohydrate contents. Iranian basil seed has higher lipid and protein contents and lower carbohydrate content than the Indian basil seed.

Table 1 Chemical composition of the basil seeds, crude and pure BSG[a] (%)

Component	Iranian Basil seeds						Indian Basil seed[c]	BSG (from Isfahan seeds)	
	Qom	Kerman	Khoram Abad	Yazd	Mashhad	Isfahan		Crude	Pure
Moisture	5.07 ± 0.15	5.11 ± 0.16	6.24 ± 0.18	5.02 ± 0.17	5.32 ± 0.16	5.51 ± 0.16	9.63 ± 0.14	7.39 ± 0.18	5.79 ± 0.12
Protein[b]	20.16 ± 0.92	19.44 ± 0.67	18.35 ± 0.83	17.94 ± 0.62	19.75 ± 0.76	18.37 ± 0.63	14.76 ± 1.52	2.01 ± 0.11	1.56 ± 0.08
Lipid[b]	23.12 ± 0.97	23.70 ± 1.01	22.92 ± 0.78	24.45 ± 0.91	22.54 ± 0.74	21.97 ± 0.71	13.8 ± 0.29	11.55 ± 0.29	9.71 ± 0.25
Ash[b]	5.38 ± 0.10	5.54 ± 0.10	4.72 ± 0.12	5.41 ± 0.11	5.34 ± 0.13	5.04 ± 0.11	7.7 ± 0.2	5.89 ± 0.14	3.32 ± 0.17
Carbohydrate (By difference)[b]	47.27 ± 0.64	47.21 ± 0.73	48.97 ± 0.87	48.38 ± 0.81	48.05 ± 0.32	50.11 ± 0.86	63.8 ± 2.01	74.19 ± 0.61	79.62 ± 0.86

[a]Values are mean ± SD of three determinations.
[b]On a dry weight basis.
[c]Mathews *et al.* (1993).

Purification of the crude BSG

Partial purification of extracted BSG had a significant effect on the quantity and quality of extracted BSG ($P < 0.01$). The purified BSG had a higher apparent viscosity at 98.9 s^{-1}, 25 °C (429 mPa s in the crude sample versus 605.6 mPa s in the pure one) and lower yield, protein and ash content (15.42%, 2.01% and 5.89% in the crude sample vs. 12.34%, 1.56% and 3.32% in the pure one) than the crude BSG extracts (Table 1).

Data analysis

The values of the response variables measured in this study are presented in Table S1. Analysis of this experimental data showed that two quadratic models were significant for extraction yield and apparent viscosity data. However, for protein content just a linear model was significant ($P < 0.01$). The most important diagnostic test to determine the adequacy of a model will be the normal probability plot of the studentised residuals. With respect to non-linear pattern of this graph for protein content model that indicates no normality in the error term, the protein content data were corrected by a Box–Cox power transformation with Lambda = 0.5 (Myers & Montgomery, 1995). Therefore, square roots of protein contents were determined and analysed. The coefficients of the significant terms in the regression models after implementing the stepwise ANOVA for response variables are presented in Table S2. Furthermore, values of R^2s, *adjusted* R^2s, *predicted* R^2s and AAD for the developed models are presented in Table S2. The values of absolute average deviation (AAD) of the models were determined as 3.61, 8.85 and 2.34 for the extraction yield, apparent viscosity and square root of protein content models, respectively. Compared to the AAD values, Baş & Boyacı (2007) had reported for various experiments, AAD values for the models in this study were very reasonable. The ANOVA results of the models that are presented in Table 2 indicated that none of the models possessed significant ($P > 0.05$) lack of fit and the R^2 values of the models were higher than 0.9. Therefore, all developed models were good predictors of dependent variables (Table S2 and Table 2). The overall effects of the process variables on the responses were further analysed and the results showed that all the process variables significantly ($P < 0.05$) influenced the extraction yield. However, the temperature and pH of gum extraction significantly influenced the apparent viscosity and for protein content of extracted BSG only the temperature was a significant variable (Table S2).

Extraction yield (Y1)

The results of ANOVA for the model equation of the extraction yield are summarised in Table S2 and Table 2. The stepwise analysis removed some of the terms from the model, but the linear terms β_1, β_2, and β_3 and the quadratic terms β_{22} and β_{33} were significant. As the regression model is determined with coded values of the variables, the size of each coefficient gives a direct measurement of the importance of each effect (Psomas *et al.*, 2007; Hosseini-Parvar *et al.*, 2008). The magnitude of coefficients showed that the temperature had more positive (linear) influence on the extraction yield than the other variables. In contrast, the pH and water/seed ratio had only negative quadratic effects on the yield (Table S2). There was no interaction effect in this model.

Apparent viscosity (Y2)

Analysis of variance for the model equation of apparent viscosity (Table S2 and Table 2) showed that the linear terms β_1, β_2 and the quadratic terms β_{11}, β_{22} and β_{33} had significant effects on apparent viscosity. Similarly, for the apparent viscosity, the magnitude of coefficients showed that the temperature had more positive linear influence on apparent viscosity than the pH (about six times more than pH effect). Conversely, the temperature had more negative quadratic effect than the pH and water/seed ratio (the magnitude of temperature effect was twice

Table 2 Analysis of variance for the fitted second order and linear polynomial models as per CCRD

Source	Extraction yield (%) Y_1	Apparent viscosity (mPa s) Y_2	Protein content (%) Y_3 Original data												Transformed data (R^2)				
	DF	SS	MS	*F*	*P*	DF	SS	MS	*F*	*P*	DF	SS	MS	*F*	*P*	DF	SS	MS	*F*	*P*
Regression	5	282.23	56.45	87.34	<0.0001	5	447307.6	89461.5	78.37	<0.0001	1	4.53	4.53	314.34	<0.0001	1	0.65	0.65	461.8	<0.0001
Residual	14	9.05	0.65			14	15980.6	1141.5			18	0.26	0.014			18	0.025	0.00141		
Lack of fit	9	7.31	0.81	2.34	0.1816	9	13749.8	1527.75	3.42	0.0943	13	0.22	0.017	2.55	0.1906	13	0.020	0.00154	1.40	0.3777
Pure error	5	1.74	0.35			5	2230.83	446.17			5	0.038	0.007			5	0.0055	0.0011		
Total	19	291.27				19	463288.2				19	4.79				19	0.68			

DF, degrees of freedom; SS, sum of square; MS, mean square; *F*, *F* value; *P*, *P* value.

more than pH effect and about 1.4 times more than water/seed ratio effect in absolute values). Similarly, we had no interaction effect in apparent viscosity model.

Protein content (Y3)

As discussed before, the protein content data were Box-Cox power transformed and ANOVA of transformed data showed that only the linear term β_1 had significant effect on the protein content. Regarding the results of overall effect of the process variables on the responses, the protein content of the extracted BSG depends only on the temperature of extraction.

Response surface and contour plotting

Contour plots and response surfaces in Fig. 1 show the profile of the responses against some of the process variables. As shown in Fig. 1e, at the most acidic pH (4.0) increasing the water/seed ratio up to sixty-six led to an increasing extraction yield, whereas, the yield decreased for ratios higher than sixty-six. On the other hand, an increase in the water/seed ratio and pH was associated with a sharp increase in extraction yield, also up to a certain point where the yield starts to decrease. The effect of a pH decline from ten to four on decreasing the extraction yield was greater than the effect of decreasing water/seed ratio (Fig. 1e). Balke & Diosady (2000) also showed a progressive effect of pH and temperature on the extraction of mucilage. However, Weber *et al.* (1974) and Cui *et al.* (1994) reported that pH did not significantly affect the extraction yield. Although, Furuta *et al.* (1998) and Somboonpanyakul *et al.* (2006) both reported that pH had a significant effect on the yield, the former believed that increasing the pH had diminishing effect on the yield, whereas the latter reported that raising the pH led to an increase in the extraction yield. Cui *et al.* (1994) also showed that water/seed ratio had no significant effect on the yield. The results also showed that as temperature increased, the extraction yield increased almost linearly regardless the value of other variables. This trend was similar to results obtained by others authors (Cui *et al.*, 1994; Milani, 2007).

In this research the effect of water/seed ratio on the apparent viscosity was not significant especially at the lowest temperature (25 °C). However, raising the extraction temperature led to a significant effect of water/seed ratio on the apparent viscosity (Fig. 1b). On the other hand, effects of the pH and water/seed ratio on the apparent viscosity were significant at higher temperatures (> 68 °C) (Figs 1b, c and 1f). It is likely that a raise in the temperature may change the ratio of heterogeneous polysaccharides of BSG (glucomannan, xylan and glucan) in the final extracted gum. Hence, this phenomenon probably is responsible for increasing the apparent viscosity. Our results on the apparent viscosity are not

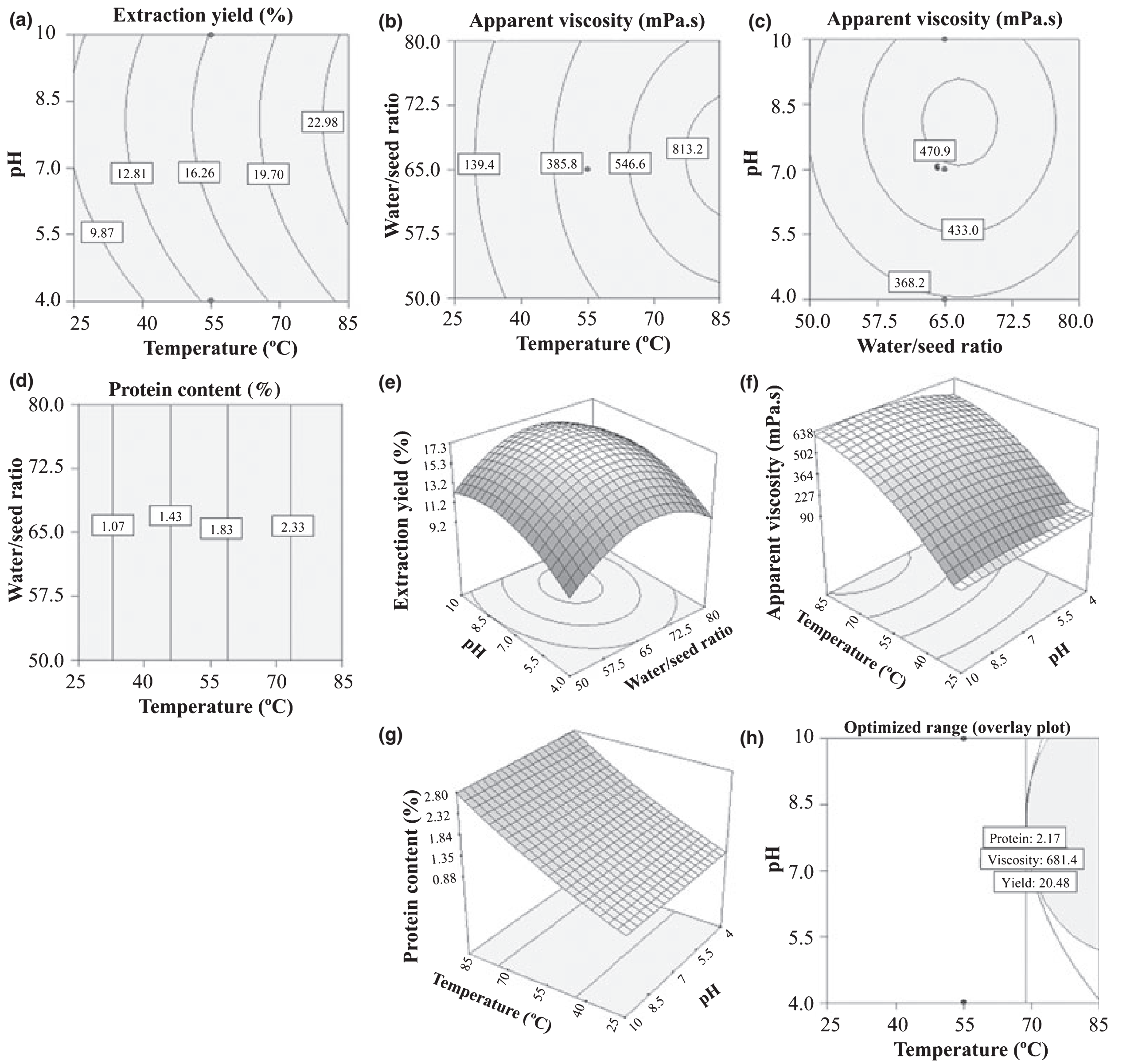

Figure 1 Contour plot and response surface illustration of the effects of pH, temperature and water/seed ratio on dependent variables of BSG extraction (the third variable in the contours and responses was held at 55 °C, pH 7 and water/seed ratio of 65:1).

in agreement with the results from Cui *et al.* (1994) and Milani *et al.* (2007). They have reported that at temperatures from 70 to 100 °C the apparent viscosity of the gum decreased. Although, in this study temperatures higher than 85 °C were not used, it is probably that a higher heat resistance of the BSG compared to the Flaxseed and Barijeh gums may be also responsible for the observed effects. As shown in Figs 1d and 1g, the effects of pH and water/seed ratio on the protein content were not significant. However, the effect of temperature on the protein content was highly significant. The protein content of extracted BSG is an impurity index. Therefore, the BSG extraction in a lower temperature led to a lower protein content and a higher purity.

Optimisation and verification

Both numerical and graphical optimisations were implemented. Determination of the optimum conditions was dependent on target parameter(s), which could be one or more of the dependent variables. Numerical optimum conditions were measured for the gum extraction based on the highest extraction yield and apparent viscosity and the lowest protein content: temperature 68.71 °C, pH 8.09 and water/seed ratio 65.98:1 resulting in the 20.49% extraction yield, 581.37 mPa s apparent viscosity and 2.17% protein content. Since sometimes the stationary points are outside of the experimental range, graphical optimisation is adopted to determine the optimum conditions for this operation (Floros & Chinnan, 1988). A graphical optimum condition is shown in Fig. 1h, where there are some ranges for any of the variables. However, the common area for three variables was the optimum condition. In Fig. 1h the water/seed ratio was held at centre value of 65:1. Adequacy of the models for predicting the optimum response values was tested by gum extraction in the optimum levels of variables obtained by the RSM optimisation. Predicted and mean of experimental values for the extraction yield (20.49 and 20.19 ± 0.48%), apparent viscosity (581.27 and 578.71 ± 4.19 mPa s) and protein content (2.17 and 2.21 ± 0.11%) showed that the experimental values were very close to the predicted values and were not statistically different at the 5% significance level. Hence, the models were good predictors for response variables.

Flow behaviour

Fitting of shear rate-shear stress data of 1% crude and pure BSG to the power law model eqn 1 showed a non-Newtonian pseudoplastic behaviour. Figure 2 shows apparent viscosity of 1% crude and pure BSG vs. shear rate. Flow behaviour indices (n) of crude and pure BSG were 0.306 (±0.009, R^2 = 0.98) and 0.283 (±0.007, R^2 = 0.98), respectively. These values were lower than CMC, pectin and carrageenan in similar concentration, indicating that the BSG is more pseudoplastic. Conversely, n values of crude and pure BSG were higher than xanthan and guar gum (Marcotte *et al.*, 2001; Riazi *et al.*, 2006). The degree of sliminess decreases with increasing deviations from the Newtonian character, and gums that exhibit a high degree of shear thinning are non-slimy in the mouth (Szczesniak & Farkas, 1962). Comparatively, both crude and pure BSG had less degree of sliminess than CMC, pectin and carrageenan. Consistency index (K) of crude and pure BSG were 17.46 (±0.41, R^2 = 0.98) and 20.22 (±0.39, R^2 = 0.98), respectively. These values were higher than the values reported by Marcotte *et al.* (2001) and Riazi *et al.* (2006) for xanthan, CMC, pectin, guar and carrageenan.

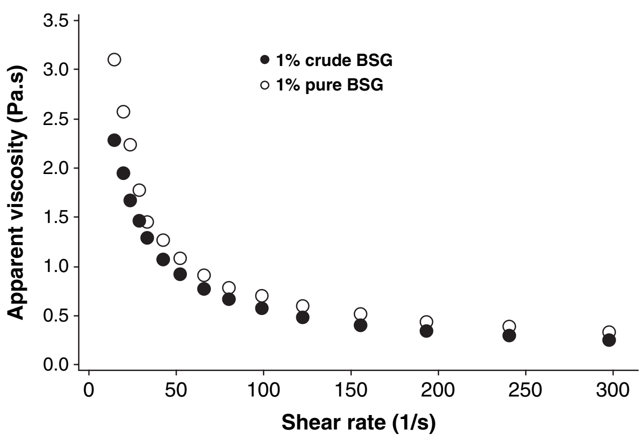

Figure 2 Apparent viscosity vs. shear rate of 1% crude and pure BSG.

Conclusion

Results of modelling by RSM showed that the extraction conditions significantly changed the extraction yield, apparent viscosity and protein content. The most important variable in this process was temperature. After temperature, pH had the most significant effect on the quantity and quality of extracted BSG. Numerical optimisation determined the optimum extraction conditions as being temperature 68.71°C, pH 8.09 and water/seed ratio 65.98:1. However, using the graphical approach the optimum ranges of variables can also be defined. Therefore, different extraction conditions can be used based on the research goals. As protein content of extracted gum is a factor of impurity, in the gum extraction process, we can choose the conditions with the lowest temperature. Power law model well described the rheological properties of the crude and pure BSG in the range of shear rate which was used in this study. Rheological parameters of BSG showed good functional properties which needs further study.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Table S1. The CCRD and the responses of dependent variables for basil seed gum extraction

Table S2. Estimated coefficients of the fitted second order polynomial

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