

Research Article

Optimization of Variables for Aqueous Extraction of Gum from *Grewia mollis* Powder

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Received 29 August 2013; Accepted 27 November 2013; Published 23 March 2014

Academic Editor: Yves Grohens

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Grewia gum is a polysaccharide derived from the inner stem bark of the edible plant *Grewia mollis*. Juss (family Tiliaceae). It is a savanna shrub that grows wild but is usually cultivated in Nigeria and Northern part of Cameroon. The main goal of the present study was to investigate the effect of aqueous extraction conditions on the extraction yield and physicochemical properties of the *Grewia mollis*. The studied aqueous extraction variables were water/powder (W/P) ratio (10:1–80:1 w/p), temperature (25.0–85.0°C), time (1–3 h), and pH (4.0–10.0). The results indicated that the aqueous extraction variables exhibited the least significant ($P < 0.05$) effect on the yield and the viscosity of the gum. The result shows that the ratio of extraction is the main factor affecting the extraction of gum. The optimized extraction condition for higher viscosity was at the powder/water ratio of 1:55.4, pH of 7, time of 1 h, and temperature of 50°C. However, the optimized extraction condition for higher yield was at the powder/water ratio of 1:80, pH of 4, time of 3 h, and temperature of 73°C.

1. Introduction

Grewia mollis is a shrub or tree widely distributed in Sudano-Sahelian region and found in Cameroon and Nigeria. The dried and pulverized inner stem bark is used as a thickening agent in some local dishes [1]. In the Adamawa region of Cameroon in particular, the powder is used as binding agent in the preparation of maize fried cake. This functionality is also exploited in Nigeria where it is used in cooking soup, or dried and pulverized to mix with bean meal to make cakes locally called in Hausa “Kosai” [2]. The functional properties of *Grewia* powder have been associated with the presence of mucilage, a polysaccharide nature [3]. In addition, the mucilage of the bark is used traditionally by the Yoruba people of Nigeria at child birth [2]. Phytochemical studies on the leaves and stem bark of *Grewia mollis* indicate

the presence of tannins, saponins, flavonoids, glycosides, phenols, and steroids and the absence of alkaloids [4].

In overall and in the limit of our knowledge, the literature on *Grewia* reported mainly the evaluation of the performance of fine powder of stem bark as binders substitute in tablet formulation [2] and the toxic effect of the powder on experimental rats [5]. Results revealed that *Grewia* gum compares favorably with the standard binder Polyvinylpyrrolidone (PVP) and could be a useful substitute binder in paracetamol tablet formulations [2]. In addition consumption of *Grewia* powder by rat models showed no significant effect on serum alkaline phosphatase activity, urea, creatinine, triglycerides, cholesterol, glucose concentrations, and body and organ weights. However significant ($P < 0.05$) increase in serum transaminases activities was observed, accompanied by decrease in food intake in rats fed 10% stem bark suggest-

ing some liver injury upon consumption of high level of the powder. While studies on *Grewia* have been interested on the powder of the stem bark, a fundamental question concerning the functionality of the isolate *Grewia* stem bark gum is still to be answered. In doing this, the extraction conditions of the gum need to be determined and the question underlying the present study is what are the effect of extraction conditions on the viscosity and the yield of *Grewia* gum since these parameters constitute the determinant factors conditioning their trade, technological and nutritional qualities? In fact the most important properties of hydrocolloids are their viscosity (including thickening and gelling) and water binding. Other significant functions include emulsion stabilisation, prevention of ice recrystallisation, and improvement of organoleptic properties [6]. And the food hydrocolloid industry represents a market of over US\$3.0 billion [7]. To our knowledge, very few if no studies have been conducted on the extraction and evaluation of the functional properties of *Grewia* gum.

Generally, hot-water treatment has been used for extraction of hydrocolloid gums and is time, temperature, pH, and water to mass ratio dependent [8]. Several studies are reported on various gums and the extracting conditions which give the optimal viscosity and yield varied from one plant species to another [9, 10]. It is important therefore to optimize the extraction process in order to obtain the highest yield and quality polysaccharides. In the extraction processes, there are multiple independent variables affecting the responding factors. In addition, the possibility of interactions between the independent variables should be considered in order to determine the optimal experimental conditions [9]. Response surface methodology (RSM) has been reported to be an effective tool and successfully used for optimization of a process when the independent variables have a combined effect on the desired response [10, 11]. However, no study has been conducted on the extraction process of *Grewia mollis* gum.

Therefore, the objectives of the present work are (1) to study the effect of extraction time, temperature, pH, and water to powder ratio on the extraction yield and viscosity of gum from stem bark *Grewia mollis* (2) to find out the optimum conditions for extraction of the gum from *Grewia mollis* powder using response surface methodology.

2. Material and Methods

2.1. Sampling and Proximate Analysis. *Grewia mollis* stem barks were procured from the local medical plant market, in Maroua, Cameroon. The stem barks were manually cleaned to remove all extraneous matter such as dust, dirt, stones, and chaff. The cleaned barks were then packed in plastic bags, sealed, and preserved in a dry and cool place. The moisture, ash, fat, and protein contents of the bark were measured [12]. The available sugar content was determined as previously described [13].

2.2. Gum Extraction Procedure. Aqueous *Grewia mollis* stem bark gum was extracted from the bark powder using distilled water (water to powder ratio 10:1 to 80:1) at pH 4 to 10 following the experimental design shown in Table 1. The

pH was adjusted with 0.1M HCl or NaOH. Water was preheated to a designated temperature before the powder was added. The powder water slurry was mixed throughout the extraction period (1 h to 3 h). Separation of the gum from the swollen powder was achieved by passing the powder through an extractor with a rotating plate that scraped the gum layer on the powder surface. The collected gum was filtered and dried in an oven (45°C overnight). The dry gum was packed and stored at cool and dry conditions [14].

2.3. Determination of the Response Variable. Two response variables were used in this work, the gum yield and the viscosity. The yield was calculated as the ratio of dry weights of the powder obtained after lyophilization to the initial powder weight and expressed as g/kg. The apparent viscosity of the hydrated samples (2.5% w/w) was measured at constant conditions (temperature 25°C, pH 7, and shear rate 1000 s⁻¹) using a rotational viscometer (Kinexus, Malvern instruments) fitted with plate geometry.

2.4. Monosaccharide Profile. The monosaccharide profile of the gum powder extracted at optimum conditions was determined as reported earlier [15]. In the procedure, 2 mg of lyophilized gum was hydrolysed in 2 mL of 2.5 M trifluoroacetic acid at 100°C for 2 h in a sealed tube under nitrogen. After hydrolysis the acid was removed on a rotary evaporator, and the hydrolysate was reduced with sodium borohydride and acetylated [16]. The resulting alditol acetate derivatives were separated on a 1.85 m × 4 mm column of 3% SP2 on 100/120 Supelcoport, in a Hewlett-Packard model 5710A gas chromatograph. The chromatography was conducted isothermally at 215°C with an N₂-carrier-gas flow rate of 60 mL/min.

2.5. Experimental Design and Statistical Analysis. Response surface methodology (RSM) was used to fit the independent variables to the response variables apparent viscosity (Pa·s) and gum yield (g/kg). A face-centered central composite design was used with 4 factors, namely, extraction temperatures (25–85°C), pH (4–10), water to seed ratio (10:1–80:1), and extraction time (1 h–3 h). The design variables in this study with actual and coded levels are shown in Table 1. The statistical package Minitab 16 was used for statistical analysis. The experimental design was composed of 30 experiments including 2⁴ full factorial design points, 8-star points, and 6-centre points. The significant terms in different models were found by analysis of variance (ANOVA) for each response. Significance was judged by determining the probability level that the *F* statistic calculated from the data is less than 5%. Numerical optimization technique of the sigma plot software was used for simultaneous optimization of the multiple responses. The desired goals for each variable and response were chosen. All the independent variables were kept within range while the responses were maximized.

3. Results and Discussion

3.1. Chemical Composition of *Grewia mollis* Bark Powder. The chemical composition of *Grewia mollis* bark powder is

TABLE 1: Matrices of the face-centered central design for the independent variables (experimental and coded levels).

Number run	Factors				Responses variables	
	Time (H)	pH	Temperature (°C)	Ratio	Viscosity (Pa.s)	Gum yield
1	(+1) 3	(−1) 4	(−1) 25	(+1) 80	0.4339	0.6226
2	(−1) 1	(−1) 4	(+1) 85	(+1) 80	0.2551	0.8174
3	(−1) 1	(+1) 10	(+1) 85	(−1) 10	0	0
4	(−1) 1	(−1) 4	(−1) 25	(−1) 10	0	0
5	(0) 2	(−1) 4	(0) 55	(0) 45	0.3119	0.3248
6	(0) 2	(+1) 10	(0) 55	(0) 45	0.3481	0.2438
7	(0) 2	(0) 7	(0) 55	(0) 45	0.8363	0.231
8	(0) 2	(0) 7	(+1) 85	(0) 45	0.3085	0.227
9	(0) 2	(0) 7	(0) 55	(0) 45	1.023	0.945
10	(0) 2	(0) 7	(0) 55	(0) 45	1.1	0.409
11	(+1) 3	(+1) 10	(−1) 25	(+1) 80	0.543	0.5436
12	(+1) 3	(+1) 10	(−1) 25	(−1) 10	0	0
13	(0) 2	(0) 7	(0) 55	(0) 45	0.834	0.285
14	(+1) 3	(+1) 10	(+1) 85	(−1) 10	0	0
15	(−1) 1	(+1) 10	(+1) 85	(+1) 80	0.3931	0.2006
16	(+1) 3	(+1) 10	(+1) 85	(+1) 80	0.3107	0.3014
17	(+1) 3	(−1) 4	(+1) 85	(−1) 10	0	0
18	(0) 2	(0) 7	(0) 55	(−1) 10	0	0
19	(−1) 1	(−1) 10	(−1) 25	(−1) 10	0	0
20	(+1) 3	(0) 7	(0) 55	(0) 45	0.6979	0.177
21	(−1) 1	(0) 7	(−1) 25	(0) 45	1.214	0.285
22	(−1) 1	(+1) 10	(−1) 25	(+1) 80	0.8223	0.1608
23	(0) 2	(0) 7	(0) 55	(+1) 80	0.4639	0.092
24	(−1) 1	(−1) 10	(−1) 25	(+1) 80	0.4084	0.3346
25	(+1) 3	(−1) 4	(−1) 25	(−1) 10	0	0
26	(0) 2	(0) 7	(0) 55	(0) 45	0.5126	0.187
27	(−1) 1	(−1) 10	(+1) 85	(−1) 10	0	0
28	(0) 2	(0) 7	(−1) 25	(0) 45	0.4045	0.272
29	(+1) 3	(+1) 10	(+1) 85	(+1) 80	0.2885	0.5906
30	(0) 2	(0) 7	(0) 55	(0) 45	1.333	0.343

presented in Table 2. The bark powder was relatively low in moisture and mainly composed of available sugars. Ash was also highly represented but the protein level was average. This was the first time, at the best of our knowledge, the proximate composition of the bark of *Grewia mollis* was reported. The composition generally reflected the composition of bark of other plants reported in the literature. In fact our previous report on *Scorodophleus zenkeri* and *Hua gabonii* barks revealed range compositions of 9.7–96 g/100 mg DM for ash, 10.2–14.2 g/100 g DM for proteins, 2.5–3 g/100 g for lipids, and 3.2–20.5 g/100 g DM for available carbohydrate. Basically the structure of plants bark is mainly composed of fibers and may contain resin, calcium oxalate cristal, tannins, and secretory elements [17]. The high level of available sugars in our bark sample reflected the high level of gum which has been shown to be essentially carbohydrate nature [3] such as Arabic gum, Tragacanth gum, and Karaya gum.

3.2. Monosaccharide Composition of the Gum. The monosaccharide composition of *Grewia* gum is presented in Figure 1.

TABLE 2: Chemical composition of *Grewia mollis* shrub powder.

Parameters	Levels
Moisture content (g/100 g)	12.3 ± 0.11
Proteins (g/100 gDM)	7.8 ± 0.55
Ash (g/100 gDM)	12.6 ± 0.05
Available sugars (g/100 gDM)	43.9 ± 2.13
Lipids (g/100 gDM)	2.5 ± 0.42

The mean relative concentration of these sugars in the polysaccharide is glucose (80%), rhamnose (19%), xylose (5%), galactose (1%), and arabinose (2%). Our results are quite similar to those previously reported by Nep and Conway [3] composed of glucose (67.1%), rhamnose (6.2%), arabinose (12.7%), xylose (2.7%), and galactose (9.61%). Our sample also presented considerable levels of galacturonic acid and glucuronic acid which have been revealed earlier in *Grewia* gum by Fourier transformed infrared spectroscopy [18]. The difference in composition of our gum with reported data may reflect the difference in the molecular weight of the

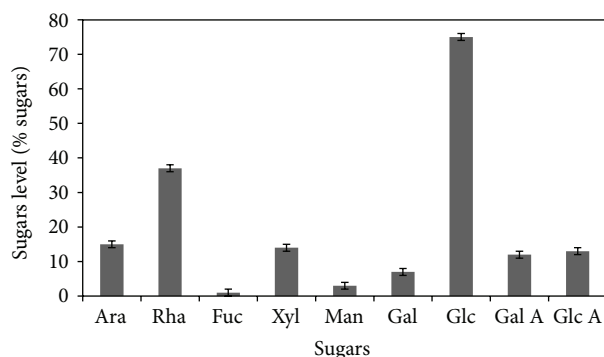


FIGURE 1: Monosaccharide profile by gas chromatography analysis.

polysaccharides which has been reported to vary depending on a number of factors such as the pathway and environment of synthesis, and the prevailing conditions under which the polysaccharide was extracted [19]. We used hot aqueous extraction in this work while Nep and Conway [3] used room temperature extraction followed by drying using varying methods.

3.3. Data Analysis of the Extraction Process. The analysis of the data generated from responses surface methodology generally assumes a second order polynomial equation showing relationship between the response variable(s) and the factors. In this equation the linear (x_i), the interactions ($x_i x_j$), and quadratic (x_i^2) effects of each factor on the response variable(s) are determined. Tables 3 and 4 give the values of the effects and the associated analysis of variances for viscosity and extraction yield, respectively. P value less than 0.05 indicated significant coefficients. In this respect the linear effect of the ratio was the most significant either for the viscosity ($P < 0.0062$) or the yield ($P < 0.0009$). In addition the quadratic effects of ratio (0.0212) and time (0.0542) were significant for the viscosity. On a comparative basis, the importance of the independent variables on viscosity could be ranked in the following order water to powder ratio > extraction time > extraction temperature > extraction pH. Koocheki et al. [11] working on extraction of Qodume Shirazi gum also found similar significant effect of water : seeds ratio and temperature on the yield and viscosity of the gum while pH has a lesser effect. Reversely Razavi et al. [20] observed a nonsignificant effect of water : seed ratio on the viscosity and a significant effect on yield. Amid and Mirhosseini [21] observed a significant effect of ratio, temperature, and pH on the extraction yield of gum from durian (*Durio zibethinus*) seeds. The difference in the effect of factors on the responses variables may reflect the chemical structure of the gum. *Grewia* gum has been shown to be composed of mainly neutral sugars, and some uronic acid [18] is revealed here as galacturonic acid and glucuronic acid.

3.4. Effect of Factors on the Yield and Viscosity. The effect of ratio water/powder, time, temperature, and pH on the responses factors is presented in Figures 2(a), 2(b), 2(c), and 2(d), respectively. The quadratic equations used were delivered when other factors were kept at the centre of the

design (coded value equal to zero). Figure 2(a) showed that an increase in water to powder ratio from 10 : 1 to 51 : 1 induced an increase in yield to an optimum of 0.78% followed by a decrease in a yield value of 0.37% when the ratio varied from 51 : 1 to 80 : 1. Similar quadratic behavior of the effect of water to powder ratio was observed on the viscosity which showed an optimum at ratio 69 : 1, equivalent to a maximum viscosity of 0.39 Pa.s. The effects of extraction time, extraction temperature, and pH represented, respectively, in Figures 2(b), 2(c), and 2(d) showed no significant variation on the viscosity and gum yield as confirmed by the ANOVA in Tables 3 and 4.

The effect of extraction time and temperature, water to mass ratio, and pH on the gum yield and viscosity has been reported in various cases. Koocheki et al. [11] reported that the yield increased exponentially with temperature and time of extraction. At higher temperature around 75°C and higher time around 3 h, yield reached nearly equilibrium. Similar trends were reported for gum materials such as flaxseed gum [9], boat-fruited *Sterculia* seeds polysaccharide [10], and Yanang leaves gum extraction [6]. These results contrasted our results and probably reflected the nature of gum origin. In fact, while our gum source is more rigid in structure, then less affected by temperature, most reported sources of gums are either seeds or leaves.

It was also demonstrated that increase in water to seed ratio tended to increase the extraction yield, probably due to the available more liquid which increased the driving force of gum out of the material [8, 22]. Conversely, some authors found a higher extraction yield at a low water to solid ratio [6]. The difference in the behavior of gum extraction yields towards the extraction time here again highlighted the effect of the nature of the gum source, but this needs to be investigated. In addition the difference in the gum structure may affect the extract yield; in particular solubility of charged gum is highly subjected to variation in pH. The effect of pH on the yield reported for some gums origins revealed minor effect in agreement with our finding [8, 10] but contrasted with findings by others who reported higher extraction yield at alkaline [23] or acidic pH [24]. According to Karazhiyan et al. [22] the effect of alkaline pH may result from hydrolysis and dissolution of insoluble constituents, which in our case may not happen due to the woody nature, shrub, of our plant material.

The effects of extraction conditions on the viscosity of extracted gums of various natures have been reported. Koocheki et al. [8] found that, as the time and temperature of extraction increased, the viscosity of the extracted gum decreases in a parabolic manner as a result of irreversible change in their conformation [25]. In addition they reported increase in water to seed ratio also conducted to a gum with lower viscosity while pH has no significant effect, particularly at lower water to seed ratio. Karazhiyan et al. [22] also reported similar effect of water to seed ratio, temperature, and pH on viscosity.

3.5. Contours Plotting, Interaction Effect, and Optimization. Figure 3 presents the contours plot of the interaction effect of water to powder ratio and extraction time on the viscosity

TABLE 3: Coefficients and analysis of variance of the effect of time, pH, temperature, and powder to water ratio on the viscosity of *Grewia* gum extract.

Source	Coefficient	Sum of square	Df	F ratio	P value
Linear	1.0657				
Constant					
Time (h)	−1.4624	0.0656	1	1.03	0.3266
pH	0.394686	0.0180	1	0.28	0.6032
Temperature (°C)	0.0353305	0.0261	1	0.41	0.5318
Ratio	0.0391614	0.6450	1	10.11	0.0062*
Quadratic					
Time × time	0.324119	0.2773	1	4.35	0.0546
pH × pH	−0.029087	0.2058	1	3.23	0.0926
Temperature × temperature	−0.000305	0.2001	1	3.14	0.0968
Ratio × ratio	0.000326	0.4221	1	6.62	0.0212*
Interaction					
Time × pH	0.00995434	0.0079	1	0.12	0.7305
Time × temperature	0.00053787	0.0001	1	0.00	0.9698
pH × temperature	−0.0000661	0.0003	1	0.00	0.9451
pH × ratio	0.00018535	0.0033	1	0.05	0.8222
Time × ratio	−0.00008227	0.0030	1	0.05	0.8321
Temperature × ratio	−0.00008382	0.0883	1	1.38	0.2578
Total error	0.956746	0.9567	15		
Total (corr.)	4.57207	4.5721	29		

* the corresponding coefficients are significant.

TABLE 4: Coefficients and analysis of variance of the effect of time, pH, temperature, and powder to water ratio on the yield of *Grewia* gum extract.

Source	Coefficient	Sum of square	Df	F ratio	P value
Linear	0.0601778				
Constant					
Time (h)	−0.452027	34.8446	1	0.10	0.7577
pH	0.0502871	619.909	1	1.76	0.2048
Temperature (°C)	0.00641689	37.7153	1	0.11	0.7482
Ratio	0.0131883	5999.3	1	17.00	0.0009*
Quadratic					
Time × time	0.0993363	20.2103	1	0.06	0.8141
pH × pH	−0.00276491	55.711	1	0.16	0.6967
Temperature × temperature	0.000007664	10.5134	1	0.03	0.8653
Ratio × ratio	−0.000088	365.476	1	1.04	0.3249
Interaction					
Time × pH	0.014648	185.664	1	0.53	0.4794
Time × temperature	−0.000926884	339.648	1	0.96	0.3421
pH × temperature	−0.000718786	101.004	1	0.24	0.6005
pH × ratio	−0.000289118	173.185	1	0.49	0.4943
Time × ratio	0.000972389	75.5734	1	0.21	0.6501
Temperature × ratio	0.0000096834	9.5103	1	0.03	0.8718
Total error	0.607627	5292.5	15		
Total (corr.)	1.80606	14902.5	29		

* the corresponding coefficients are significant.

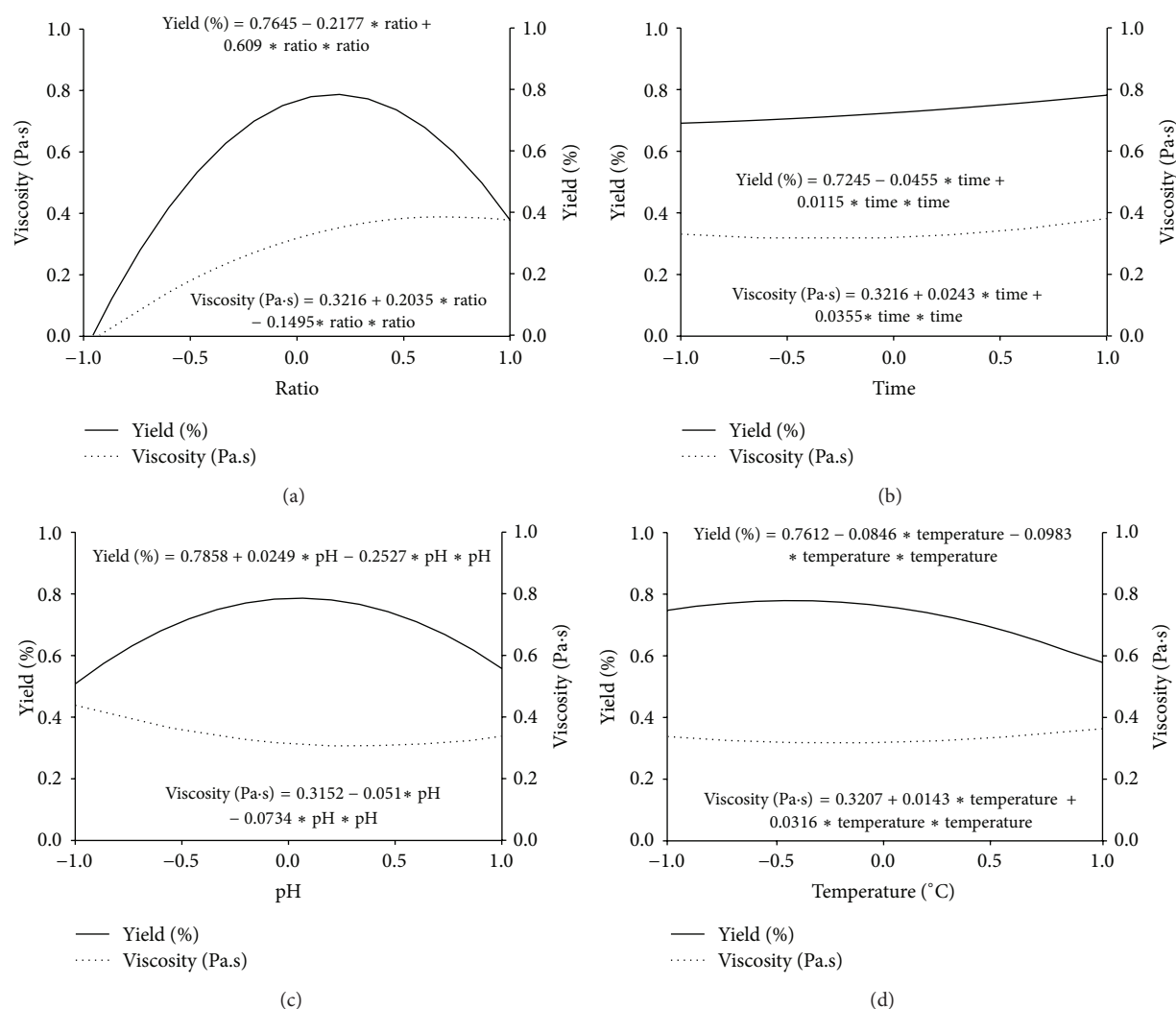


FIGURE 2: Quadratic representation of the effect of powder to water ratio (a), extraction time (b), extraction pH (c), and temperature (d) on the viscosity and yield of *Grewia* gum.

and yield of *Grewia* gum. Each contour plot was drawn when the other parameters were at the centre of the domain, that is, ratio 55:1, time 2 h, temperature 55°C, and pH 7. As shown in Figure 3(a), the extraction time had no effect on the viscosity at water/powder ratio 10–40 and 60–80, while, between the ratio ranges 40 and 60, an increase in the extraction time induced a decline in the viscosity from 1.2 Pa.s to less than 0.8 Pa.s. On the other hand, irrespective of the extraction time, an increase in water/powder ratio from 10 to 55 was associated with an increase in viscosity after which a decline was observed. The highest viscosity was 1.2 Pa.s observed only at lower extraction time, a maximum which diminished as the extraction time increased. The interaction effects of the water/powder ratio and time on the yield showed no marked change with viscosity fluctuating between 0.1 and 0.4.

The interaction effect of pH and water to powder ratio shown in Figure 4 revealed that pH exerted influence on the viscosity at water/powder ratio around 50:1. In these conditions an increase in pH from 4 to 7 led to an increase in viscosity (from 0.4 to 0.8 Pa.s) above which a decrease

was observed (Figure 4(a)). The effect on yield was also quite visible at water/powder ratio higher than 50:1 where an increase in pH led a nonsignificant decrease in yield from 0.5% to 0.2%. The effect of temperature was similar to that of time with no significant effect at lower water powder ratio and some observed effect around ratio 40–60 (Figure 5). In this range of ratio an increase in temperature seemed to reduce viscosity and similar change was observed on yield.

The results obtained in this study revealed that viscosity and yield were most affected by the water : powder ratio, and to a lesser extent by time, pH, and temperature of extraction. In order to identify the optimal conditions of *Grewia* gum extraction, the contours plot presented was used. In this respect the most suitable condition was considered optimal for *Grewia* gum extraction at the highest extraction yield and viscosity. Optimum was achieved graphically by identifying zones of maximum viscosity and gum yield as stripped in the contours plots in Figures 3, 4, and 5. The optimal extraction conditions zones for *Grewia* gum viscosity corresponded to the range temperature 25°C–85°C, pH 6–8, water to powder

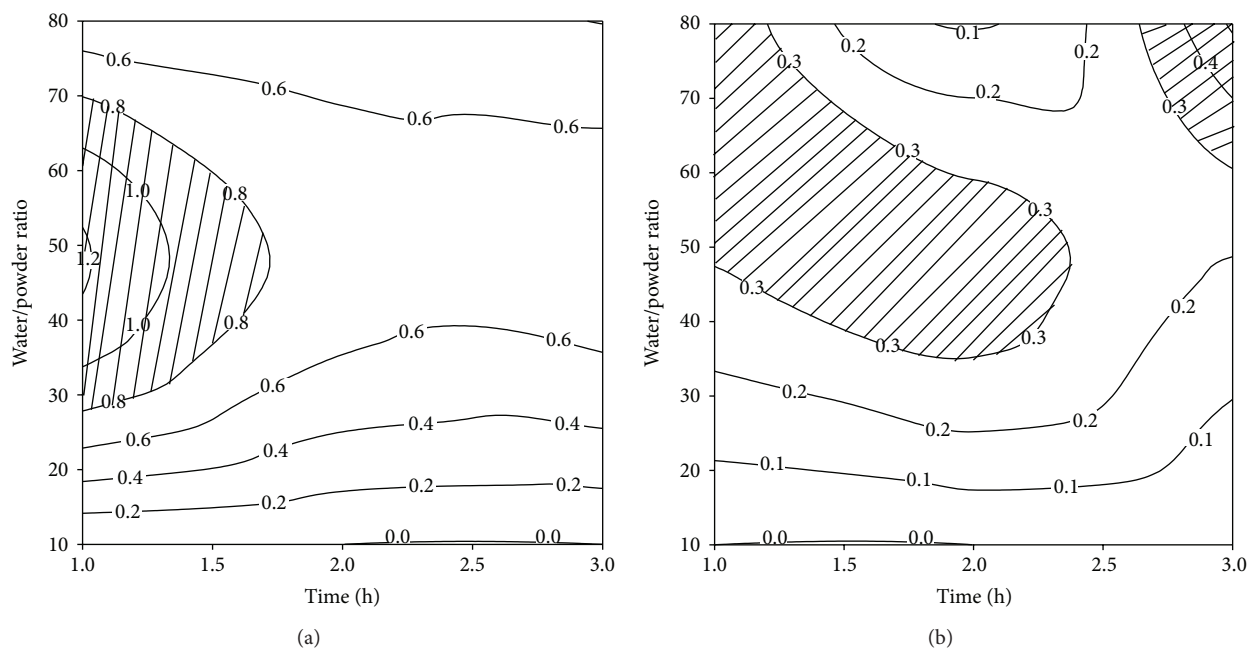


FIGURE 3: Interaction effects of water/powder ratio and extraction time on the viscosity Pa-s (a) and yield % (b). pH and time extraction conditions were 7 and 2 h, respectively.

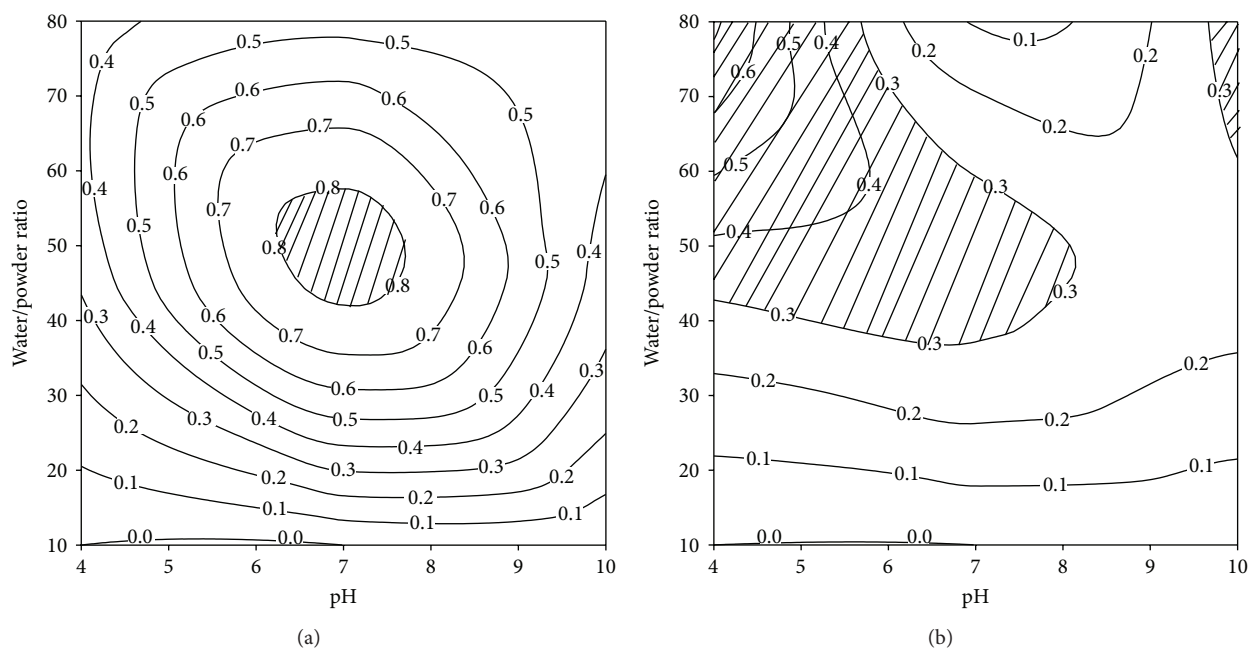


FIGURE 4: Interaction effects of water/powder ratio and pH on the viscosity Pa-s (a) and yield % (b) of *Grewia* gum. Extraction time and temperature conditions were 2 h and 55°C, respectively.

ratio 40:1–60:1, and time of extraction 1 h–1.5 h while the corresponding zone for optimum yield was temperature 30–60°C, pH 4–7, water to powder ratio 50:1–70:1, and time of extraction 1–2 h, respectively. The optimum conditions of extraction were also computed for each yield and viscosity and the values given in Table 5 reflected the optimum determined graphically. Multiple graphical optimizations were performed by drawing the overlaid contour plot in order

to establish the overall optimum area of aqueous extraction condition as shown in Figure 6. Since only water to powder ratio and time had significant effects on the viscosity and yield, only the graphs involving the water to shrub ratio and time as factors were used. Based on this, the extraction condition that maximized viscosity and yield of *Grewia* gum was water to powder ratio 50:1–60:1 and extraction time 1–1.5 h.

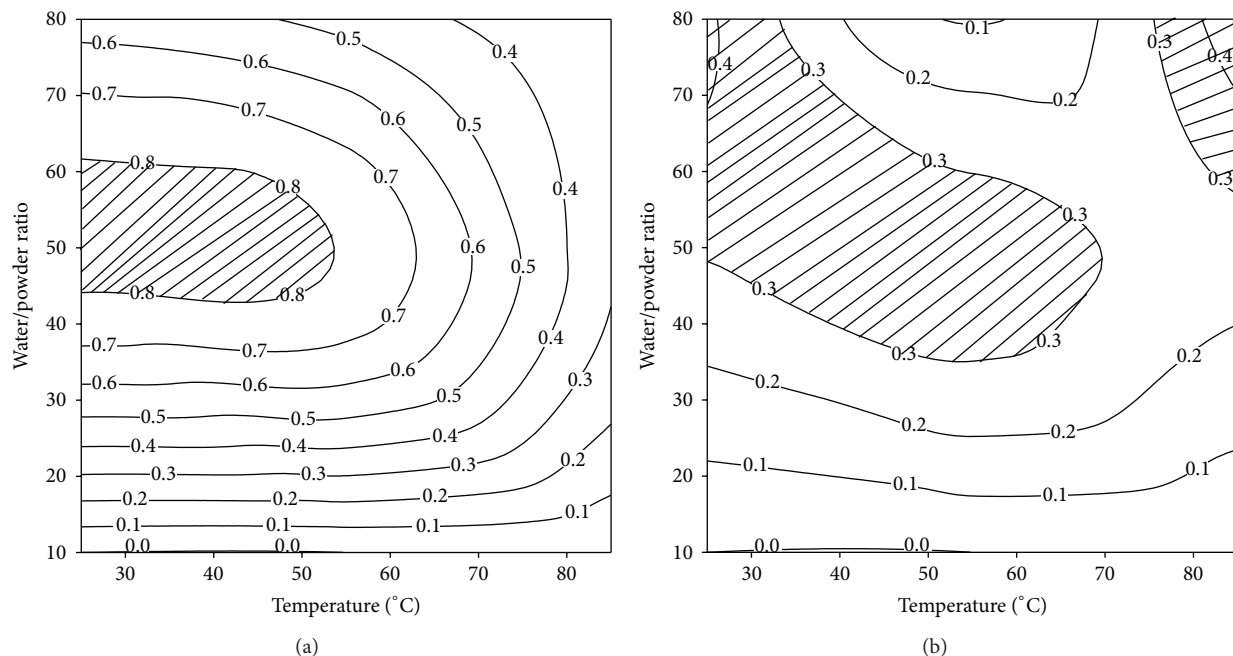


FIGURE 5: Interaction effects of water/powder ratio and temperature on the viscosity Pa-s (a) and yield % (b) of *Grewia* gum. Extraction time and pH conditions were 2 h and 7, respectively.

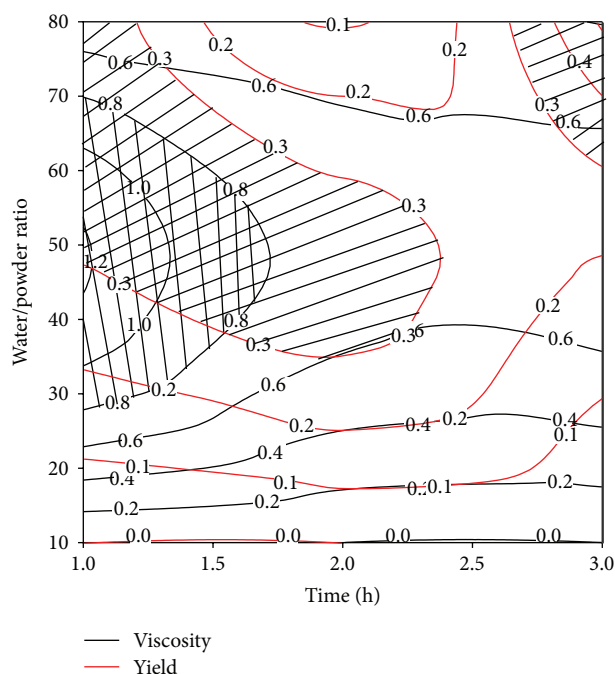


FIGURE 6: Overlaid plotting for multiple optimization of aqueous extraction of *Grewia* shrub gum.

As shown in Table 5 the numerical optimum corresponded to temperature 73°C, time 1 h, pH 7.0, and water to powder ratio 55 : 1. In these conditions, the gum was extracted with a yield of 0.32 g/100 g DM and the gum solution possessed a viscosity of 0.98 Pa-s, values which were close to desired values of 0.4 g/100 g DM and 1.2 Pa-s, respectively.

TABLE 5: Computed predicted optimum conditions of extraction of *Grewia mollis* gum.

Factor	Optimum viscosity	Optimum yield
Times	1.0	3
pH	7.1	4
Temperature	50.3	73.2
Water : shrub ratio	55.4 : 1	80 : 1

Bold values were overlaid selected optimum conditions.

The viscosity of 2.5% gum extracted in these conditions falls within the range of values generally reported for other plants gum: 581.4 mPa-s for *Ocimum basilicum* seed gum [20] and 518.9 mPa-s for *Lepidium perfoliatum* [8]. In addition, the yield, however, was lower compared to most seeds gums reported in previous studies such as Yanang gum 4.54% [6], Flaxseed gum 7.9% [9], *Opuntia mucilage* 19.4% [26], and Mesquite seed gum 24.9% [25], but much higher compared to 1.2% reported for *Durio zibethinus* seed gum [27].

Based on its lower extraction yield compared to the most commercial gum, the use of *Grewia* gum as a novel food hydrocolloid is questionable. In addition the part of the plant used, the shrub, can also lead to the destruction of the plants if harvesting is not appropriately conducted.

4. Conclusion

Results showed that extraction conditions significantly influenced the extraction yield and apparent viscosity. The most important variable is the water to powder ratio, whereas the effects of extraction temperature, time, and pH are less important. Increasing water to powder ratio resulted in an

increase yield and viscosity up to maximum at ratio 55:1 from which a decrease is observed. Based on numerical optimization and significant factors, the optimal extraction condition of *Grewia* gums is temperature 73°C, pH 7, time 1 (h), and water to powder ratio 55:1. This investigation confirms the use of *Grewia* gum as gelling agent and the carbohydrate nature of its gum. Studies of its gelling power need to be studied. However the yield is lower compared to commercial gum and this hypothesizes its eventual use as a new source of hydrocolloid for industry.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgment

The authors would like to thank the Cooperation pour la Recherche Universitaire (CORUS-IRD ref 6052, FRANCE) for financial support.

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