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Foaming behaviour of liquorice (*Glycyrrhiza glabra*) extract

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Abstract

The foaming behaviour of liquorice extract was investigated using response surface methodology with concentration (0.1–0.3 w/v%) and whipping time (5–25 s) being the independent variables. A first-order kinetics was applied for the kinetic analyses of the foam collapse and foam decay rate constants were calculated. Regression equations for predicting overrun (O) and foam decay rate constant (k) were developed. Results suggest that concentration had a significant effect ($P \leqslant 0.01$) on overrun and foam stability. The overrun increased with concentration and whipping time. However, the effect of whipping time on O was less pronounced. Foam stability was enhanced with the increase in concentration. The foam decay rate was observed to be mainly dependent on the concentration of sample ($P \leqslant 0.01$) and decreased with the increase in concentration. The effect of whipping time on foam stability was observed to be insignificant ($P \leqslant 0.01$) compared with concentration. The magnitude of changes with whipping time were observed to be more pronounced for the overrun than for the stability of liquorice extract foam.

Keywords: Foam; Liquorice; Extract

1. Introduction

Liquorice (*Glycyrrhiza glabra*) is a perennial leguminous plant, widespread in Spain, Italy, Turkey, Israel, Syria, Iran, China, Russia (Casulli & Ippolito, 1995). The plant, having multi-year production- cycle, has blue, violet flowers (de Mastro, Circella, DeMastro, Palevitch & Putievsky, 1993). Liquorice roots are cylindrical in shape having a diameter of 0.5–2.5 cm and length of 15–20 cm (Marzi et al., 1993). Liquorice is a rare plant and contains anti-allergic and anti-inflammatory substances (Dimitrova, Varbanova, Paeva, Angelova & Guteva, 1994). The root is gathered as a herb and is used in medicine. Extracts from liquorice roots have been used in the treatment of abdominal complaints including gastric ulcers and dermatitis (Elgamal, Abdel-Hady, Hanna, Mahran & Duddeck, 1990; Schambelan, 1994). They are involved in the recipes of cough syrups and also are used to mask the bitter taste of medicines.

The liquorice root contains various sugars (upto 18%), flavonoids, saponoids, sterols, amino acids, starch and gums. The active ingredient in liquorice is mainly glycyrrhizin, a triterpenoid glycoside, which constitutes up to 14% of total soluble solids content (Baran & Fenercioğlu, 1991) giving the characteristic sweet taste of the liquorice root. Glycyrrhizin is low in calories and can be used in the form of ammonium glycyrrhizin (AG) or monoammonium glycyrrhizin (MAG) in the foods and beverages. AG is about 50 times as sweet as cane sugar, imparts a tan coloration and slight liquorice flavour. However, liquorice flavour and colour are repressed in MAG. The liquorice root extract has been widely used in the food industry as a sweetening agent, a flavour potentiator and a flavour modifier (Cook, 1973). It has also found widespread usage as a foaming agent in alcoholic and non-alcoholic beverages (Arestov, 1976), in confectionery products (Mansvelt, 1979), in halva and sweets (Kafka, Sosnovskii & Kharlamova, 1970; Portnova et al., 1991). Commercially, the liquorice root extract is supplied in concentrated or powdered form for ease of transportation (Baran & Fenercioğlu, 1991). For use in products, the concentrate or powder extract is diluted with water to the required concentration.

There is a growing commercial interest in using liquorice root extract in food foams. However, little is known about the foaming behaviour of the extract. Investigation of foaming behaviour of liquorice extract may be useful for process design, especially for the utilisation of heat exchangers and pumps. Foaming properties of liquorice extract also influence the sensory quality and shelf-life of the final product. In describing

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foaming behaviour, it is necessary to make a distinction between overrun and foam stability. The overrun gives the amount of foam produced per unit weight of sample and is related to the amount of interfacial area produced per unit weight or concentration. However, foam stability represents the ability of protein to stabilize the foam against gravitational and mechanical stresses. The former relates to the rapid adsorption and rearrangement of molecules whereas the later is imparted by the formation of flexible cohesive film at the interface (Dickinson, 1989).

Liquorice root extract can be used to modify food foams, to enhance foam stability or to impart flavour. It can also be used in the development of new foamy foods. The present paper investigates the foaming behaviour of liquorice root extract, as changed by concentration and whipping time, using response surface methodology.

2. Materials and methods

2.1. Extraction

Liquorice (*Glycyrrhiza glabra*) root (mc 12%) was purchased from a local market and disintegrated to thread-like pieces. Fragments were mixed with water at a liquorice root to water weight ratio of 20:1 and shaken by a shaker in a thermostat tank at 50°C for 2 h. The mixture was centrifuged (Hettich, Roto Silenta III) for 15 min at 230×*g* and the decantate was filtered (Whatman No. 41). The clear extract was concentrated to 50°Brix in a laboratory rotary vacuum evaporator (Bibby Sterilin Ltd., RE100) at 50°C. The soluble solids content was measured using a refractometer (Opton, F.G. Bode & Co., Hamburg). Then the concentrate was dried in a vacuum oven drier at 40°C to 15% moisture content. The foaming experiments were performed by diluting the liquorice extract powder to required concentrations using phosphate buffer (pH 7.0, 50 mM).

2.2. Overrun and foam stability

One hundered millilitres of liquorice extract-buffer solution was prepared according to the concentrations given in Table 1. The solution was transferred to the graduated cylinder of a Waring Blender which was placed into a thermostatic bath at 25°C. The solution was kept in the cylinder for 30 min for temperature equilibration and then whipped at full speed (Wright & Hemmant, 1987) according to the whipping times given in Table 1. When the blender was stopped, the foam volume was immediately recorded to give overrun, O (ml/ml), defined as the volume of gas incorporated per ml of aqueous solution. Foam stability was monitored by measuring the change in the volume of foam produced in 5 s time intervals. Kinetic analyses of foam stability were done by applying first order kinetics. Rate constants for the foam collapse (k) at different concentrations and whipping times were calculated by regression analysis using a linear least square method and foam stability was described in terms of foam decay rate constant. The statistical significance of data was performed by Analysis of Variance (ANOVA).

2.3. Experimental design

The variation of the two independent variables, liquorice extract concentration (wt%) and whipping time (s), was studied by choosing a two-factor composite rotatable design with six replicates at the centre point (Mullen & Ennis, 1979). Ranges for the independent variables are shown in Table 1. These ranges of operating variables were found to be useful in investigating the effects of variations by unpublished preliminary studies. Response surface methodology was applied to the data using a statistical package, Design Expert version 5.0 (State-Ease, Inc. Mineapolis, MN, USA). A polynomial equation (first order) was fitted to the data to obtain a regression equation. Statistical significances of the terms in the regression equations were examined. Response surface plots were generated with the same software.

3. Results and discussion

Concentration and whipping time are two important parameters affecting the foaming behaviour of food products (Halling, 1981). In the present study the influence of concentration and whipping time on the foam stability and overrun of liquorice extract was investigated using response surface methodology. The regression equations giving the relationship between responses

Table 1
Independent variables and experimental design levels used in foaming experiments ($\alpha = 1.414$), the coded axial distance from the centre point

	Standardised levels				
	$-\alpha$	-1	0	$+1$	$+\alpha$
Whipping time (s)	5	7.93	15	22.07	25
Liquorice extract concentration (w/v) %	0.05	0.13	0.2	0.27	0.3

(overrun and foam decay rate constant) and the parameters studied (concentration and whipping time) are given in Table 2. Results show that liquorice extract concentration ($P \leqslant 0.01$) and whipping time ($P \leqslant 0.05$) were statistically significant on overrun of the samples studied.

Fig. 1 shows the effect of concentration and whipping time on the overrun of liquorice extract. The overrun obtained increases with the increase in concentration. This probably results from the presence of large number of molecules at the interface at high concentrations (Cherry & McWatters, 1981). The effect of whipping time on overrun is less pronounced compared with concentration. A short whipping may be enough for the molecules to reach the interface and form a protective adsorbed layer around the bubbles. Therefore, an extended period of whipping may have little effect on the creation of a new interface.

Table 2
Regression equation coefficients for overrun (O, ml/ml) and foam decay rate constant (k, s^{-1}) of liquorice extract in terms of actual variables (X: concentration, w/v%; Y: whipping time, s)

	O ($r^2=0.91$)	k ($r^2=0.93$)
Constant	+1.88	+0.02
X	+0.37[a]	-8.81×10^{-3}[a]
Y	+0.16[b]	-1.73×10^{-3}
X^2	+0.07	-2.62×10^{-3}[b]
Y^2	−0.05	-1.62×10^{-3}
XY	+0.07	-5.00×10^{-4}

[a] $P \leqslant 0.01$ (significant at 99% confidence interval).
[b] $P \leqslant 0.05$ (significant at 95% confidence interval).

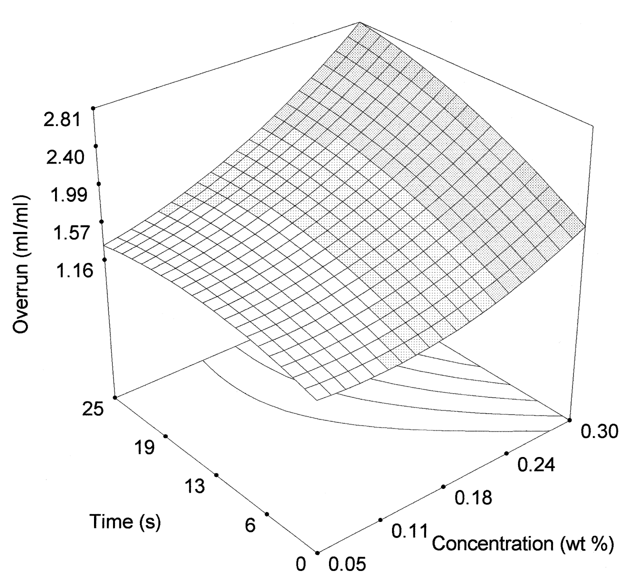

Fig. 1. Effect of concentration and whipping time on the overrun (O) of liquorice extract.

The stability of certain protein foams have been shown to follow first-order kinetics (Yu & Damodaran, 1991). In phenomenological terms, decay of the liquorice extract foam, expressed in terms of foam volume disappearance with time, can be assumed to follow first-order kinetics, which can be expressed as

$$V_t/V_0 = K_0 \exp(-kt)$$

where V_0 is the initial volume at $t=0$, V_t is the foam volume at $t=t$, k is the rate constant and K_0 is an empirical constant. A plot of log (V_t/V_0) against t gives the rate constant k. An analysis of data (0.2% liquorice extract solution whipped for 15 s) gives the value $k=0.025\pm0.002$ s^{-1} (Fig. 2).

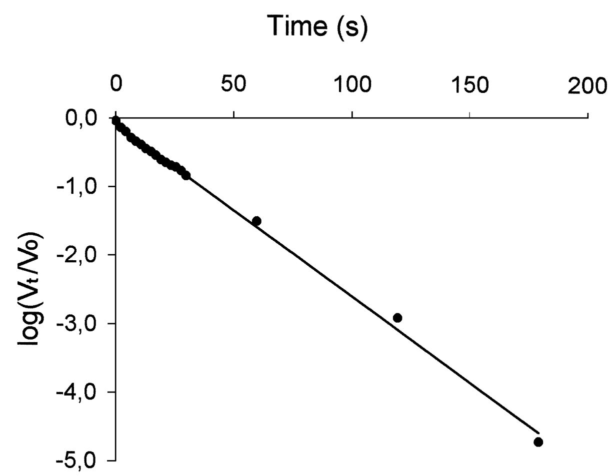

Fig. 2. Application of first-order kinetics to foam disappearance data obtained from 0.2 % liquorice extract solution whipped for 15 s. (—) shows fitted line, (●) represents actual data.

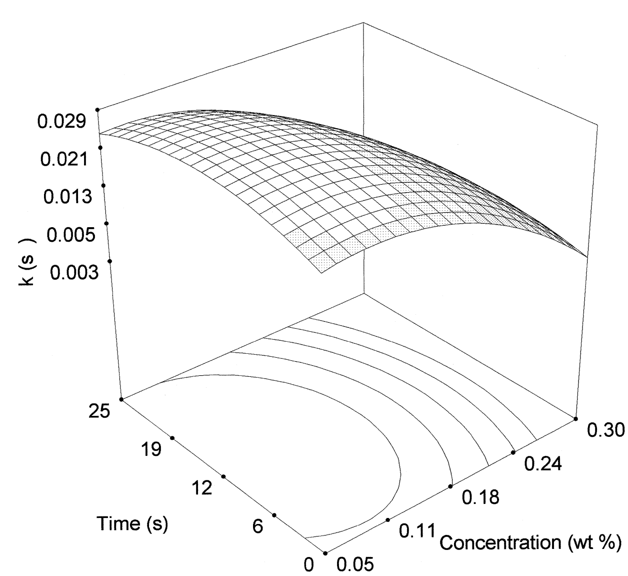

Fig. 3. The change of foam decay rate constant (k) with concentration of liquorice extract and whipping time.

Foam decay rate constants were calculated by changing liquorice extract concentration and whipping time. Fig. 3 shows the variation in the rate constant as a function of these parameters. As the concentration and whipping time increase, the magnitude of foam decay rate constant decreases, indicating an enhanced stability. The coefficients of regression equation and r^2 are given in Table 2. The regression equation reveals that the foam decay rate mainly depends on the concentration of sample ($P \leqslant 0.01$) and the whipping time is statistically insignificant compared with concentration of liquorice root extract ($P \leqslant 0.01$). Foam stability can be expected to increase with increased bulk concentration (Izgi, 1995), since more molecules may adsorb and provide a good coverage around the bubbles to impart stability. The increase in stability due to the change in whipping time may arise from the adsorption of molecules at the stressed interface during whipping to eliminate the surface tension gradients and to provide better packing. Therefore, the foam stability may be improved due to film rupture and coalescence. The magnitude of changes with whipping time were observed to be more pronounced for the overrun than for the stability of liquorice extract foam (Table 2).

Consequently, the stability and the amount of foam can be optimised by changing the concentration in the context of process design, sensory attributes and shelf-life.

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