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Foaming Properties of White Wheat Flour-Yoghurt Mixture as Affected by Fermentation

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ABSTRACT

Effect of fermentation on the foam stability (FS) and overrun (O) of a white wheat flour-yoghurt mixture was investigated using response surface methodology with concentration (0·5–1·5%, w/v) and whipping time (30–120 s) being the independent variables. Regression equations for predicting the FS and O were developed. Results suggest that concentration had the most pronounced effect on the overrun while concentration and whipping time were both effective on foam stability. Response surface plots suggest that fermentation causes a decrease in the overrun, possibly resulting from the change in the structure of protein due to breaking down of molecules into small nitrogenous molecules as a result of fermentation. Fermented sample has a better foam stability (i.e., 8·0 ± 0·1 min) than unfermented control sample (i.e., 5·0 ± 0·1 min) at the same concentration and whipping time.

Keywords: foaming, fermentation, wheat flour-yoghurt mixture.

INTRODUCTION

Fermented cereal-yoghurt mixtures play an important role in the diets of many people in the Middle East, Asia, Africa and some parts in Europe[1]. Methods for preparation for such mixtures may vary from one place to another, but cereals, mostly wheat and corn, and yoghurt are always the two major components[2]. Cereals, in grain or flour form, are mixed with yoghurt and the mixture is left to ferment by its indigenous microflora at ambient temperature for several days (1 to 7 days) followed by drying and grinding. The resultant powder is mixed with water, simmered and consumed as soup or gruel for feeding children, adults and elderly people[3]. Some common examples of such products are tarhana in Turkey and Greece, kishk in Iraq and Egypt, and tahonya/talkuna in Hungary and Finland[1]. While cereal-yoghurt mixtures can be used for part of any meal, they are often eaten at breakfast. The practical nutritional importance of cereal-yoghurt mixtures is their improvement of the basic cereal protein diet by adding animal protein in a highly acceptable form. Dried cereal-yoghurt mixtures are not hygroscopic and can be stored in open jars for 2–3 years without deterioration, and are shelf-stable under ambient conditions. The low moisture content (3–9%) and the low pH (4·0–4·5) of the final products are a safeguard against the growth of pathogenic and spoilage micro-organisms[4].

Fermentation can cause desirable or undesirable modifications in the foaming properties of cereal-

Table I Independent variables and experimental design levels used in foaming experiments ($\alpha = 1{\cdot}682$, the coded axial distance from the centre point of the design)

	Standardised levels				
	$-\alpha$	-1	0	$+1$	$+\alpha$
Concentration (%, w/v)	5·0	6·4	10·0	13·5	15·0
Whipping time (s)	30	43	75	106	120

ABBREVIATIONS USED: FS = foam stability [s]; O = overrun [mL/mL].

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Table II Regression equation coefficients for overrun (O, mL/mL) and foam stability (FS, s) (X_1: % concentration, w/v; X_2: whipping time, s)

	Fermented		Unfermented control	
	O ($r^2=0{\cdot}91$)	FS ($r^2=0{\cdot}95$)	O ($r^2=0{\cdot}89$)	FS ($r^2=0{\cdot}93$)
Constant	+0·27	+544·0	−0·008	−19·7
X_1	+0·41**	−759·8*	+0·41**	+28·5*
X_2	−0·002	−7·2**	+0·004	+0·2*
X_1^2		+588·9*		−10·5*
X_2^2		+0·05		−0·3
X_1X_2		+1·6		−0·02

* $p \leqq 0{\cdot}01$ (significant at 99% confidence interval).
** $p \leqq 0{\cdot}05$ (significant at 95% confidence interval).

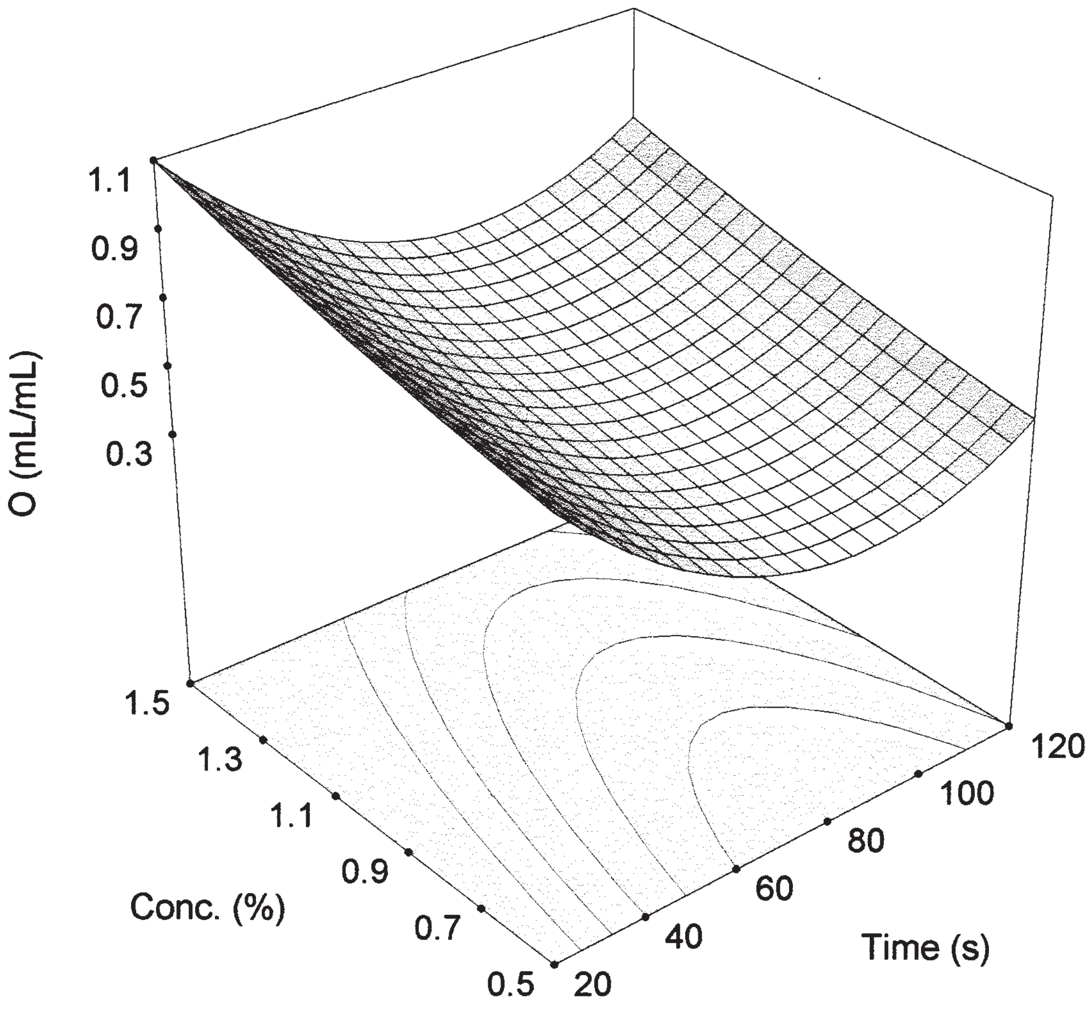

Figure 1 Effect of concentration and whipping time on the overrun (O) of fermented white wheat flour-yoghurt mixture.

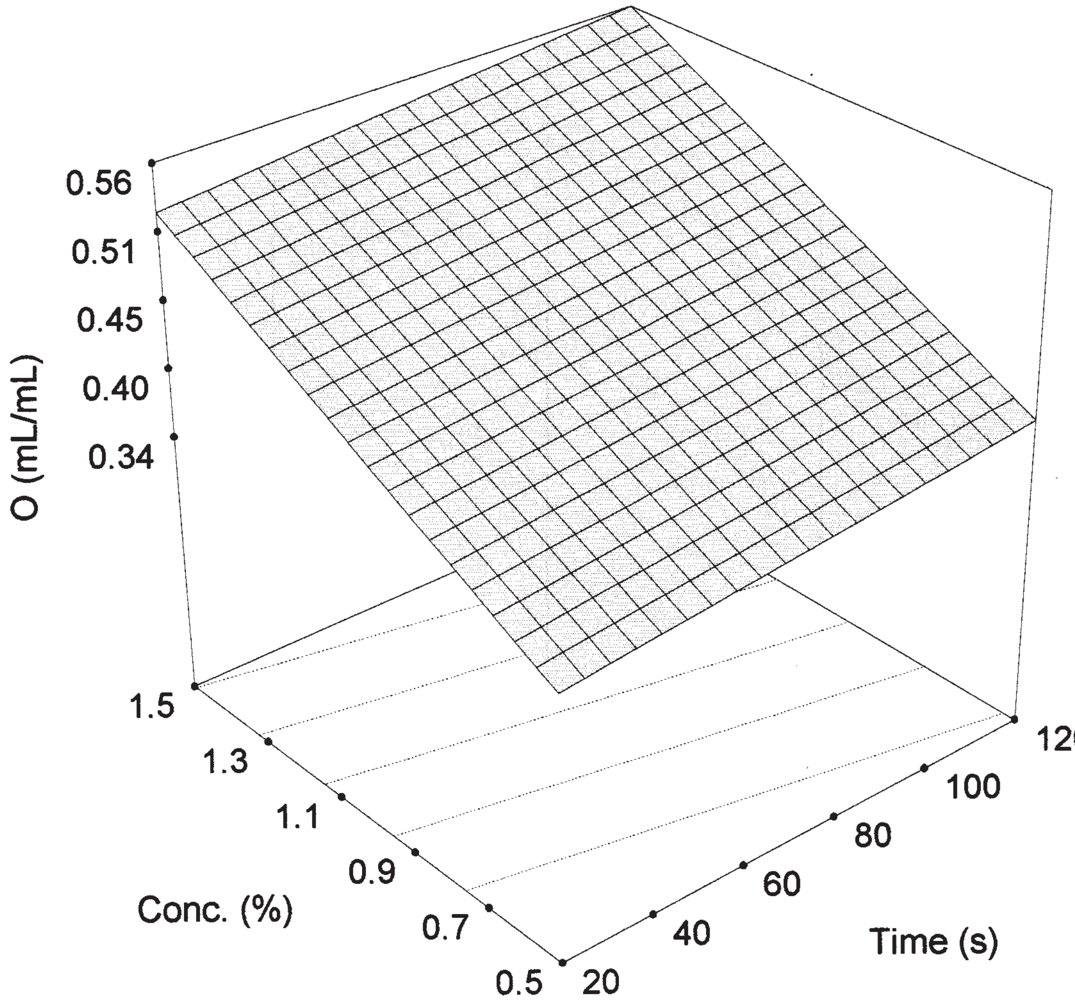

Figure 2 Effect of concentration and whipping time on the overrun (O) of unfermented (control) white wheat flour-yoghurt mixture.

based foods[5]. The chemical and nutritional changes during fermentation[3,6] and extrusion[7] of a white wheat flour-yoghurt mixture have been studied. There is a growing commercial interest in producing wheat flour-yoghurt-based soups due to their nutritional advantages. The knowledge of foaming behaviour of such soups may be very useful for process design, especially for the utilisation of heat exchangers and pumps. The whipping properties also influence the sensory quality, particularly mouth feel. The purpose of this study was to determine the effect of fermentation on the foaming properties of a white wheat flour-yoghurt mixture at different concentrations (0·5–1·5%, w/v) and whipping times (30–120 s) using response surface methodology.

MATERIALS

The wheat flour used was regular, finely ground, commercial white wheat flour (Piyale Un, Izmir, Turkey) with a moisture content of 13·0% (w/w) and a protein content of 12·3% (w/w). The full-fat cow's milk (Pinar Milk Company, Izmir, Turkey) to be used in yoghurt preparation was heat-treated (vigorously boiled for 1 min) and cooled to 43 °C. The commercial lyophilised yoghurt starter culture (1:1) of *Lactobacillus delbrueckii* ssp. *bulgaricus* (Pinar Milk Company, Izmir, Turkey) and *Streptococcus salivarius* ssp. *thermophilus* (Pinar Milk Company, Izmir, Turkey), was inoculated into 20 mL heat-treated milk (2·5%, w/w) and incubated at 43 °C for 6 h to give activated culture. The activated

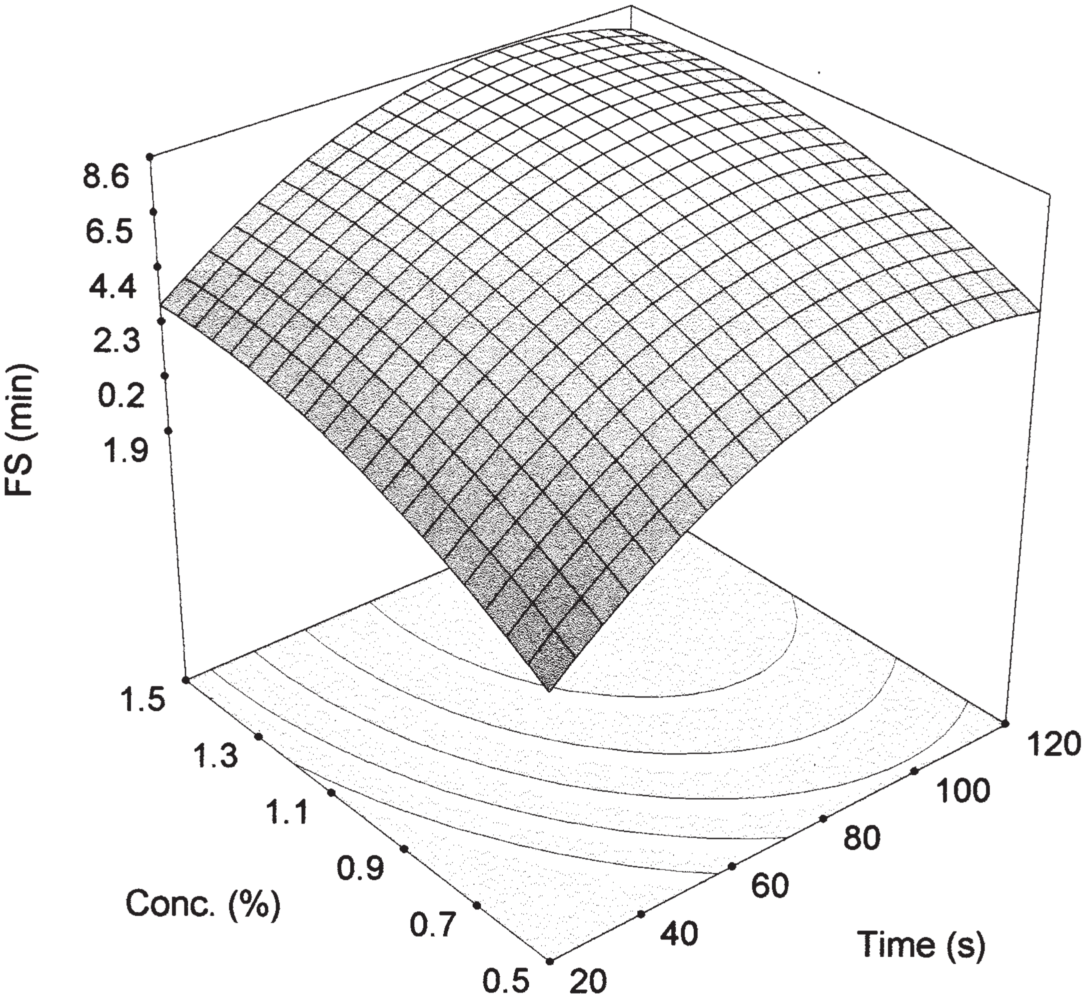

Figure 3 Effect of concentration and whipping time on the foam stability (FS) of unfermented (control) white wheat flour-yoghurt mixture.

culture was used in the yoghurt preparation. The heat-treated milk (50 mL) was mixed with activated culture (2·5%, w/w), stirred and incubated at 43 °C for 10 h to ferment. After fermentation the yoghurt was stored at 4 °C until used. The yoghurt obtained (pH 4·3) had a crude fat content of 3·4% (w/w) determined by the Soxhlet method using petroleum ether as the solvent[8].

METHODS

Preparation of fermented wheat flour-yoghurt mixture

White wheat flour (25·0 g, dry basis) was mixed with 25·0 g yoghurt in a sterile beaker covered with aluminium foil. The resulting batter was then incubated at 30 °C for 48 h to ferment to a pH value of 4·5. After fermentation, the mixture was kept at 4 °C until used in the foaming experiments (approximately for 30 min). An unfermented control sample was prepared as above without fermentation.

Overrun and foam stability

A wheat flour-yoghurt mixture + distilled water suspension (100 mL), prepared according to the concentrations given in Table I, was mixed for 10 min by means of a magnetic stirrer and filtered (Whatman No. 2). The resulting clear solution was transferred to a Waring blender and whipped at full speed according to the whipping times given

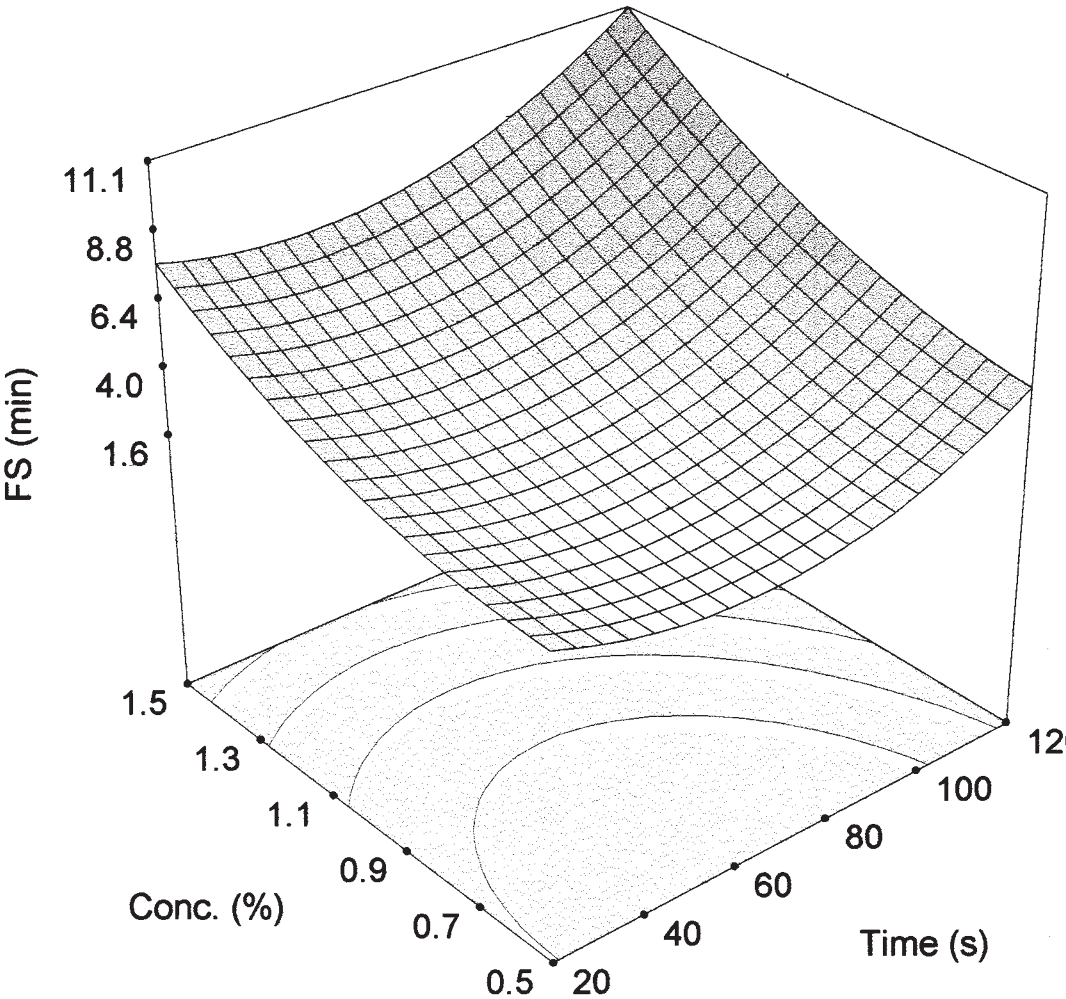

Figure 4 Effect of concentration and whipping time on the foam stability (FS) of fermented white wheat flour-yoghurt mixture.

in Table I. The blend was slowly poured into a 250-mL measuring cylinder and the volume of the foam formed was recorded after 10 s. Then, the overrun O (the volume of gas incorparated per mL of aqueous suspension, mL/mL) was calculated using the foam volume measured. Foam stability, FS (s), was determined as the time elapsed until half of the original foam had disappeared. The pH of unfermented sample was adjusted to 4·5 using 0·1 N HCl prior to whipping. The temperature of the samples was kept constant at 20 °C using a thermostatically controlled water bath throughout the foaming experiments.

Experimental design and statistical analysis

A two-factor composite rotatable design was chosen to study the contribution of the two independent variables: wheat flour-yoghurt mixture concentration (% w/v) and whipping time (s). Ranges of the selected independent variables are shown in Table I (concentration: 5·0–15·0%, w/v; whipping time: 30–120 s). Composite rotatable designs have been used in food research[9] due to the smaller number of experiments needed while maintaining statistical effectiveness. Response surface methodology was applied to the data using a commercial statistical package, Design-Expert version 5.0 (Stat-Ease, Inc., Minneapolis, U.S.A). Polynomial equations (i.e., first or second order models) were fitted to the data to obtain regression equations. The model with a higher regression coefficient (r^2) was then chosen to represent the actual data points. Statistical significances of the terms in the regression equations were examined. Response surface plots were generated using the same software.

RESULTS AND DISCUSSION

Concentration and whipping time are the two important parameters affecting the foaming behaviour of a food product[10] provided that other conditions are kept constant. In this study, the effect of concentration and whipping time on the foam stability and the overrun of a white wheat flour-yoghurt mixture were investigated using response surface methodology. Although the response surface plots were generated using the fitted data rather than the actual data points, the regression coefficients (r^2) given in Table II indicate a high correlation of the actual data to the fitted data. The coefficients in the regression equation can be used to examine the significance of each term relative to each other[11]. It was observed that while both concentration and whipping time were significant on the foam stability, whipping time was not significant ($p \leqq 0{\cdot}05$) for the overrun of the samples studied (Table II). Interaction of concentration with whipping time was not significant ($p \leqq 0{\cdot}05$) (Table II).

The effect of concentration and whipping time on the overrun of fermented and unfermented control sample are given in Figure 1 and 2, respectively. The overrun increases linearly with the concentration of both samples. This can be explained by the presence of large number of protein molecules at the interface[12]. The highest overrun obtained for the fermented sample is $1{\cdot}09 \pm 0{\cdot}03$ mL/mL (Fig. 1) while this was found as $0{\cdot}60 \pm 0{\cdot}03$ mL/mL (Fig. 2) for the unfermented control sample. At a concentration of 0·5% (w/v), the overrun obtained with the unfermented control sample is approximately half the overrun obtained with the fermented sample at the same concentration. This may result from the breakdown of proteins as a result of fermentation, as has been previously observed[6]. Although the molecular weight and hydrophobicity distribution of fragments were not measured, a 10% increase in protein solubility (relative to the protein solubility before fermentation) was observed due to fermentation. Whipping time has no effect on the overrun of the unfermented control sample (Fig. 2). However, the overrun of the fermented sample is reduced as the whipping time increases (Fig. 1).

Figure 3 shows the foam stability of the unfermented control sample as a function of time and concentration. Foam stability increases with the increase in concentration. It also increases as the whipping time is extended, reaching a plateau value after 90 s. The improvement in the foam stability can be explained by the formation of a thick film at high concentrations[13] and the aggregation of proteins over long whipping[14].

The fermented sample has a better foam stability (i.e., $8 \pm 0{\cdot}1$ min) at 1·5% (w/v) and 30 s whipping time (Fig. 4) than the unfermented control sample (i.e., $5 \pm 0{\cdot}1$ min) at the same processing conditions (Fig. 3). Foam stability of the fermented sample increases with concentration and time. The breakdown of proteins into small fragments may facilitate the diffusion and spreading of these fragments at the air/water interface[15]. The fragments may pack effectively at the interface because of their sizes[16]. The increase in foam stability at high concentrations may result from the intermolecular cross-linking of fragments[17].

The main objective of this study was to investigate the effect of changes in concentration and whipping time on the foaming properties of fermented and unfermented white wheat flour-yoghurt mixture. The non-soluble particles such as insoluble proteins and starch granules influence the foaming properties of mixtures under practical conditions. Considering that the soluble proteins and protein fragments available in aqueous suspension of sample mixtures play a role in the foam formation, and the insoluble matter may have detrimental effect to foam stability, the foaming properties were investigated using soluble constituents. Therefore, the numerical values presented in this paper should not be directly transferred to real systems where sample mixture is not filtered.

CONCLUSIONS

The results show that concentration had the most pronounced effect on the overrun of a white wheat flour-yoghurt mixture while concentration and whipping time were both effective on foam stability. Response surface plots suggest that fermentation causes a decrease in the overrun, possibly resulting from the change in the structure of protein due to breaking down of molecules into small nitrogenous molecules as a result of fermentation. Fermented sample has a better foam stability (i.e., $8 \pm 0{\cdot}1$ min) than unfermented control sample (i.e., $5 \pm 0{\cdot}1$ min) at the same concentration and whipping time.

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