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ORIGINAL PAPER

The preparation of mayonnaise containing spent brewer's yeast β- glucan as a fat replacer

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Abstract

The work presents the application of β-glucan prepared from spent brewer's yeast as a fat replacer in mayonnaise. Fat was partially substituted by β-glucan at levels of 25, 50, 75 %. Physicochemical, rheological and microbiological analyses of mayonnaises obtained were performed.

The results indicated that all mayonnaises containing β-glucan had higher water content and lower caloric value (244-597 kcal/100g) than the control sample without β-glucan (778 kcal/100g) and these differences increased with increasing substitution levels of β-glucan. The pH values of the mayonnaise samples (3.85-3.88) decreased in time at room temperature or at 4-6^{0}C temperature storage with increasing substitution levels of β-glucan. Microbial loadings of all analyzed mayonnaises were in the acceptable limit throughout the storage time that was min.63 days at 25-30^{0}C and min. 91 days at 4-6^{0}C. All mayonnaises exhibited thixotropic shear thinning behavior under steady shear tests and were rheologically classified as more solid – like gels. The mayonnaise with 50 % β-glucan showed higher storage stability than the other samples. It has been demonstrated that spent brewer's yeast β-glucan can be used as a fat replacer in mayonnaise as well as an emulsion stabilizer.

Keywords: rheology, stability, emulsion, caloric value

Introduction

The spent brewer's yeast cell wall has precious components such as the polysaccharides with many applications in the food industry and pharmaceutical domain [1,2,3]. The cell wall of *Saccharomyces cerevisiae* is mainly composed of β-glucans (~ 50%) and mannoproteins (~ 40%) but small amount of chitin and lipids, too [4]. β-Glucan is a polymer of glucose that has several chemotherapeutic effects which include the inhibition of tumor development, enhancement of defense against bacterial, viral, fungal and parasitic challenges and the activation of macrophages; β-glucan plays an important role in the skin protection and in the immune system [5].

β-Glucan is poorly utilized in the human digestion tract and functions as a non–caloric food [6].Mayonnaise is an oil-in-water emulsion and is a widely consumed product. Mayonnaise must contain at least 78.5% total fat [7] that contribute to the appearance, flavor, texture and stability of food emulsions but the fat has an important ,, negative role'' in development of cardiovascular diseases, hypertension and obesity. Therefore, the light mayonnaise production is a beneficial solution for human health. Application of β-glucans as a fat replacer is little published in the literature. Ma and Barbosa- Canovas [8] made a rheological characterization of mayonnaise with different xanthan gum concentrations; Volikakis & al. [9] used oat- β-glucan as a fat replacer in low-fat-cheese; Kontogiorgos & al. [10] showed that cereal β-glucans could be used as stabilizers in model salad dressings and Worrasinchai & al. [6] demonstrated the spent brewer's yeast β-glucan use as a fat replacer in mayonnaise.
In this study were investigated the advantages and disadvantages of partial β-glucan substitution for fat in mayonnaise after sensorial, physicochemical, microbiological and rheological analysis.

Materials and methods

β-Glucan preparation

β-Glucan was prepared according to the procedure described in our preceding article: spent brewer's yeast slurry was autolysed for 48 h at 50^0C. The cell wall obtained by centrifugation was treated by a single alkaline extraction using 5 volumes of 1N NaOH at 90^0C, for 1 h followed by 1N HCl treatment then washed with 3-5 volumes of distilled water. The β-glucan product achieved was a beige homogeneous slick paste [11].This β-glucan had the following chemical composition in percentage (w/w): moisture 93.68, fat 0.07, protein 0.19, carbohydrate 5.91 and ash 0.14. The β-glucan percentage was 3.5 w/w. The pH value was 4.56.

Mayonnaise preparation

The ingredients for mayonnaises were purchased from a local hipermarket.Four mayonnaise samples were prepared in this study (200 g of each sample): Z0, Z1, Z2, Z3.The full fat (Z0) mayonnaise recipe was very little modified from that recommended by Worrasinchai & al. [6].The recipe contained the following ingredients in percentage (w/w): pure egg yolk 7.32, sunflower oil 82.14, salt 0.72, vinegar (5% acid acetic) 8.75, mustard 0.36, sugar 0.35 and ground black pepper 0.35. In Z1, Z2, Z3 samples, sunflower oil was replaced by β-glucan at levels of 25% (41.06 g β-glucan), 50% (82.14 g β-glucan) and 75% (123.22 g β-glucan) of total oil utilized. The preparation process had the following steps: firstly pure egg yolk and vinegar were mixed together then other ingredients (including β-glucan, except oil) and finally sunflower oil that was very slowly added by a continuous stirrer with Mixer Braun MR 4000 with 250 Watt power for 5 minutes. The each sample was divided in two parts that were aseptically transferred in sterile glass recipients with caps and left one-day at room temperature (25-30^0C). The second day the samples were analyzed then one half of the samples was introduced in fridge at 4 – 6^0C and the other half was maintained at room temperature.

1. Sensory analysis

Sensory evaluation was carried out on the mayonnaise samples after one – day storage at room temperature. Five examiners have evaluated the following sensory characteristics : appearance, color, odor and consistence.

2. Storage stability

Mayonnaise stability was determined by monitoring the samples during storage every week at room temperature for 2.5 months and at 4-6^0C for 4 months, for the profound structural modifications, decrease of consistence and the oil separation (the mayonnaise destabilization).

3. Physicochemical analysis

The pH was measured at a temperature of 25^0C using a Mettler Toledo S20 K pH meter. Three different samples were taken for each pH measurement of mayonnaises. Protein and ash contents were determined according to AOAC official methods [12], using the Kjeldahl analyzer and Laboratory Furnace LMH 07/12. Fat content was determined by Bligh and Dyer method [13] after was tested the Soxhlet method. Moisture was determined with Thermobalance Precisa XM 60. Carbohydrates were determined by subtracting the sum of protein, fat, ash and moisture percentages from 100%. The assays were performed in triplicate. The caloric value (kcal/100 g) for each mayonnaise was calculated by the formula [14]:

Caloric value = (4 x protein) + (9 x fat) + (4 x carbohydrate)

4. Microbiological analysis

Total plate count of each sample (1g) was determined by serial (1:10) dilution using the BCA culture medium and Koch cultural method, utilizing a Labo Autoclave SANYO and

a CRUMA microbiological niche with laminar flow. Colonies were counted after the plates were incubated for 48 h at 37^0C in a STERICELL drying oven.

5. Rheological analysis

Rheological measurements were performed with a rheometer AR 2000 Ex - TA Instrument CMT with a cone and plate geometry sensor (40 mm diameter, 2^0 cone angle). All samples were measured at 25^0C. The measurements were carried out at a gap distance of 0.05 mm. Firstly was determined the linear viscoelastic range with strain sweep (0.1 – 30%) at a fixed frequency of 10Hz. A dynamic frequency sweep was conducted by applying a constant strain of 0.5% which was within the linear region in a frequency range between 0.1 and 100 Hz. The shear stress – the shear rate relation was analyzed for the flow behavior study. The studied shear rate range was 0-300 s^{-1} when resulted the „ up curves" and 300-0 s^{-1} when resulted the „down curves". The shear stress – the shear rate data were analyzed by using the power law model that is the simplest of the available models. The power law equation is as follows:

$$\sigma = k \gamma^n \text{, where:}$$

σ is shear stress (Pa); γ is shear rate (s^{-1}); k is the consistency coefficient ($Pa.s^n$); n is the flow behavior index (-)

Results and discussions

1. The appearance and the color samples after one-day storage at room temperature decreasing with increasing the substitution levels of β-glucan. The control sample Z0 was a homogeneous, dense, polished paste but in the mayonnaise with β-glucan appeared the small uniform distributed particles so that the Z1, Z2, Z3 samples lost the polish appearance and the uniformity. The Z0 sample had a shiny bright yellow color whereas the other samples had a pale beige color. These characteristics were in accord with Karas & al. [15]. The mayonnaise consistence was different from sample to sample. The Z2 sample had the loudest consistence among the all four mayonnaises and the Z3 sample had the smallest consistence. The odor was not significantly influenced by the β-glucan substitution.

2. As regards the mayonnaises stability it can be observed from Fig. 1 that the Z2 sample had the highest stability (77 days at room temperature, 119 days at 4- 6^0C) and the Z3 sample had the smallest stability (63 days at room temperature, 91 days at 4- 6^0C). A β-glucan content of 50% in mayonnaise increases the samples consistence and the samples stability. This conclusion was attributed to an increase in viscosity of the continuous phase and a formation of weak gel network by the added β-glucan [1]. This result confirms the findings of Thammakiti & al. [1] and Kontogiorgos & al. [10] that spent brewer's yeast β-glucan can efficiently stabilize the oil-in-water emulsion. Although Z3 sample has the highest β-glucan percentage, the Z3 mayonnaise has the smallest stability. Perhaps a bigger moisture content of this sample brought by fat replacer can destabilize the oil-in-water emulsion.

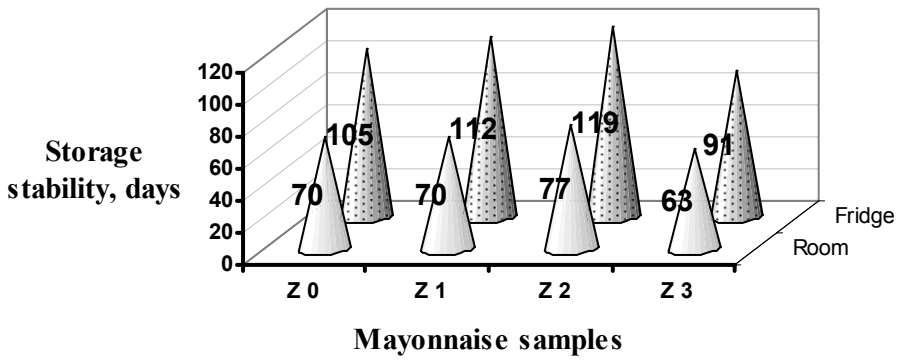

Figure 1. The storage stability of mayonnaises at room or fridge temperature

3. The pH values at one-day storage was very handy for the 4 samples. After 63 days at room temperature and 91 days at 4- 6^0C it was observed a little pH value increase for Z0 sample and a pH value decrease for mayonnaise with β glucan (Fig.2). This phenomenon was interpreted by Karas & al. [15] as follows: the samples with fat replacer, by having an higher water content, contained more microbial loadings, which might be the cause of the growth of acid tolerant microorganisms such as lactic acid bacteria. Because of the activity of lactic acid bacteria, the pH during storage decreased. In any event, it is recommended that mayonnaise made with unpasteurized egg to be prepared with vinegar to a pH of 4.1 or less and held at room temperature for at least 24 h to reduce the risk from microorganisms [16].

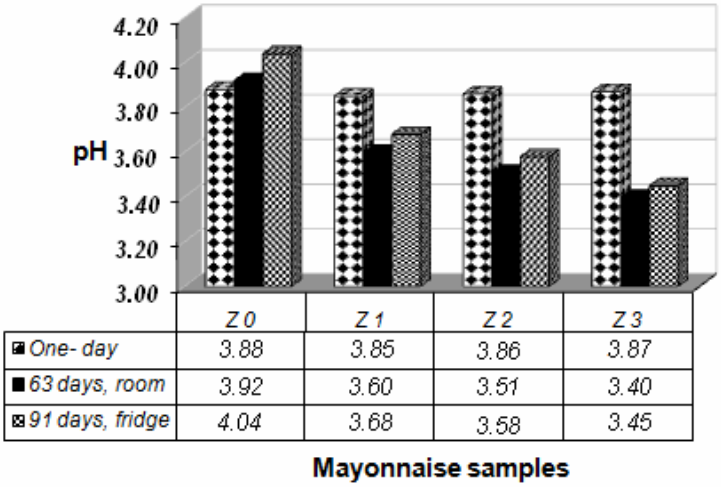

Figure 2. Mayonnaises pH evolution over the storage time

The moisture and carbohydrate content increased with increasing levels of β-glucan substitution due to a very high moisture content of β-glucan preparation and itself β-glucan content, respectively. No significant differences between Z0 and Z1, Z2, Z3 samples in protein and ash content was found. One might expect that the caloric values of samples with the fat replacer were significantly reduced with increasing the levels of β-glucan substitution because the β-glucan itself is a non-caloric product. In fact, the objective of this study was the decrease of mayonnaise calorie numbers (Table 1).

Table 1. Chemical composition and caloric values of mayonnaise samples

Samples	Moisture, (%, w/w)	Fat (%, w/w)	Carbohydrate (%, w/w)	Protein (%, w/w)	Ash (%, w/w)	Caloric values, (Kcal/100g)
Z 0	11.04	85.12	1.74	1.42	0.68	778.72
Z 1	30.31	64.34	3.10	1.51	0.74	597.5
Z 2	49.40	43.83	4.33	1.64	0.80	418.35
Z 3	68.06	24.05	5.31	1.73	0.85	244.61

4. Fig. 3 shows the total plate counts from all samples in time at room temperature. The Z0 mayonnaise had the highest total plate count (252 cfu/g) after one day storage as compared with that of the Z1, Z2, Z3 samples that have the smaller values and insignificant differences between samples. The higher oil content of the Z0 sample gave the higher possibility that microorganisms may reside in the oil phase and is not seen the acid and pH effect in the aqueous phase [17]. The total plate count of Z0 sample decreased up to 57 cfu/g at room temperature after 63 day. The reduction of microbial loadings was due to the effect of undissociated acetic acid solubilized into the oil phase [6]. After yet one week (in the

destabilization moment), the total plate count of Z0 sample increased up to 71 cfu/g, probably due to acid tolerant microorganisms development. In the Z1, Z2, Z3 samples case, the total plate count advanced over the whole storage period because the mayonnaise with greater moisture contained more microorganisms such as lactic acid bacteria [15, 17].

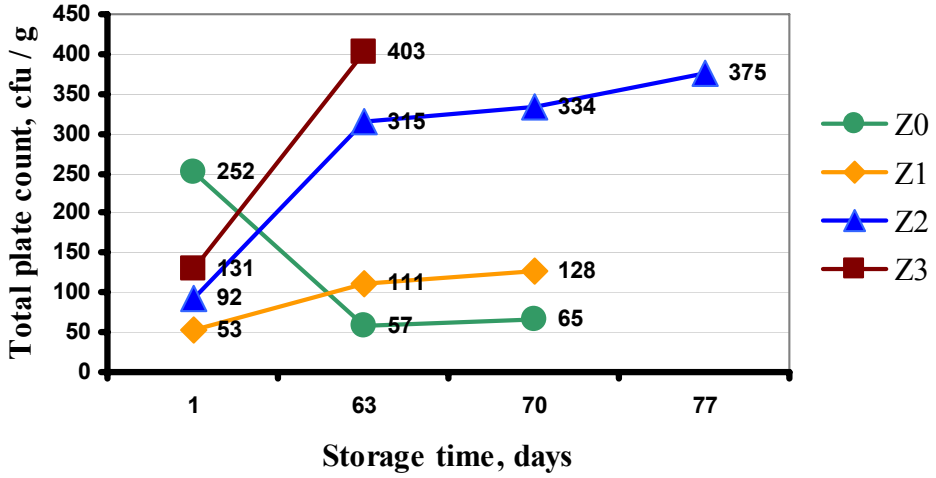

Figure 3. Total plate count of mayonnaise samples maintained at room temperature

Fig. 4 shows the total plate counts from all samples in time at 4-6^{0}C where the low temperature retarded the microorganisms growth and advanced the mayonnaise stability.

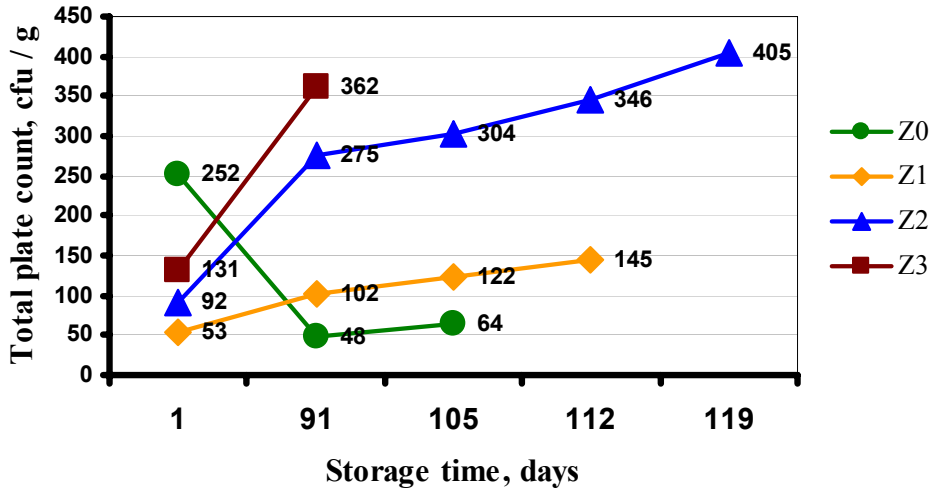

Figure 4. Total plate count of mayonnaise samples maintained at fridge temperature

5. Fig.5 presents the flow curves of mayonnaises. All samples showed the lower values of shear stress over down curves than the values of shear stress over up curves at the same values of shear rate. When the shear rate is slowed, these mayonnaises present hysteresis loops in flow behavior. Furthermore, the whole shear process exhibited the shear stress decrease over time and viscosity decrease, too. Consequently, the mayonnaise samples have the nenewtonian thixotropic fluid characteristics [18]. The area within the hysteresis loop is the energy consumed in structure breakdown .This area is an important informative criterion of thixotropic behavior [18]. We suppose that the area decrease represents the stability increase measure. Thence, the Z2 sample with 643.9 Pa/s has the biggest stability at

shear process versus the Z0 sample (712.6 Pa/s), Z1 sample (1,637 Pa/s) and Z3 sample (9,315 Pa/s).

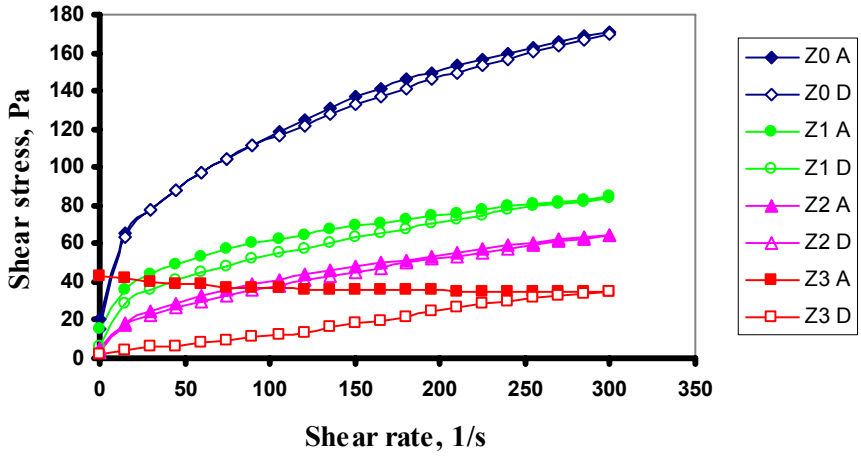

Figure 5. Flow curves of mayonnaise samples (ZA- up curves, ZD- down curves)

In table 2 it is observed that the consistency coefficient (K) values were decreased and the index (n) increased when the samples were subjected to the ascending and then descending of the shear rate. Moreover, the flow index (n) values were less than 1.0. Therefore, the mayonnaises samples behaved as shear thinning fluids. These findings are in agreement with the results of Ma & Barbosa-Canovas [15]. Three samples of this study contains in their chemical composition proteins and polysaccharides. The macromolecular substances responsible for network formation in food systems are primarily polysaccharides and proteins. The unifying property among these foods is that they are mostly fluids but respond as viscoelastic solids with a high degree of elasticity [19].

Table 2. Values of power law model parameters

Sample	Up curves			Down curves		
	K (Pa.s^n)	n	r^2	K (Pa.s^n)	n	r^2
Z 0	24.85	0.33	0.889	24.12	0.34	0.881
Z 1	17.90	0.27	0.852	9.46	0.38	0.908
Z 2	5.9	0.42	0.924	4.24	0.47	0.943
Z 3	-	-	-	7.43	0.49	0.992

In Fig. 6, 7, 8, 9 was reproduced the variation of storage and loss modulus, respectively (G', G''), based on the frequency change for each analyzed sample. The G' modulus was larger than G'' throughout the tested frequency range in all cases. Therewith, the loss tangents (tan δ) from Fig.10 is smaller than 1.0. Both, these results improved that the all samples was found to be more solid-like, shows that the material is highly structured , suggests that the particles are highly associated due to the colloidal forces and indicates whether elastic or viscous properties predominate in a sample [19, 20]. In Fig. 6 the G' increase from 135.9 Pa (0.1 Hz frequency) to 206.1Pa (31.62 Hz) then decrease to 78.2 Pa (100 Hz) in the Z0 case.

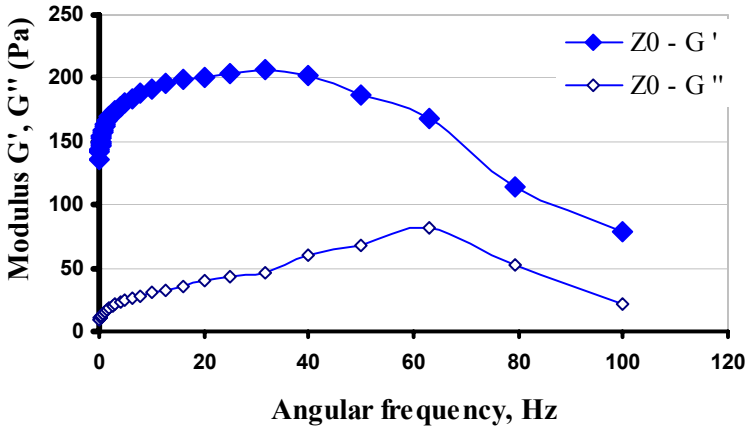

Figure 6. Dynamic mechanical spectra of Z0 mayonnaise sample

In Fig. 7 the G' increase from 138.6 Pa (0.1 Hz) to 194.6 Pa (31.62 Hz) then decrease to 122.4 Pa (100 Hz) in the Z1 case. The storage energy decrease at a larger frequency than 31.62 Hz commencing probably a mayonnaise destabilization process. The 25% β-glucan percentage did not produce significant effects on the mayonnaise stability.

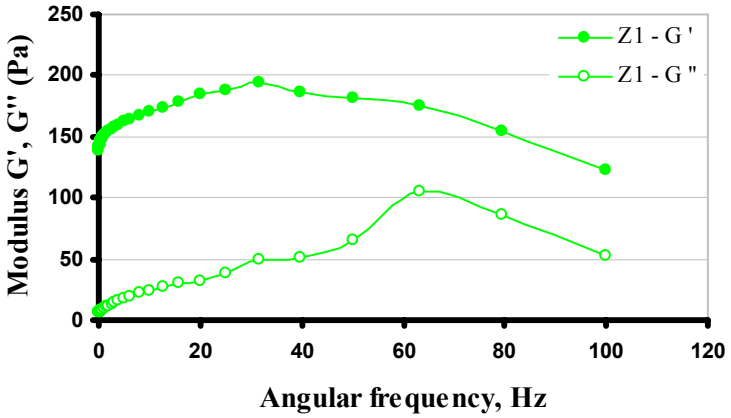

Figure 7. Dynamic mechanical spectra of Z1 mayonnaise sample

In Fig. 8 the G' increases from 115.3 Pa to 231.3 Pa over the whole range of frequency studied. The 50% β-glucan percentage increased the storage energy value due to mayonnaise network stabilization by the added β-glucan. Therefore, the β-glucan can be perhaps considered a stabilization agent at 50% fat replacer in mayonnaise because the β-glucan strengthens the gel structure of mayonnaises [6].

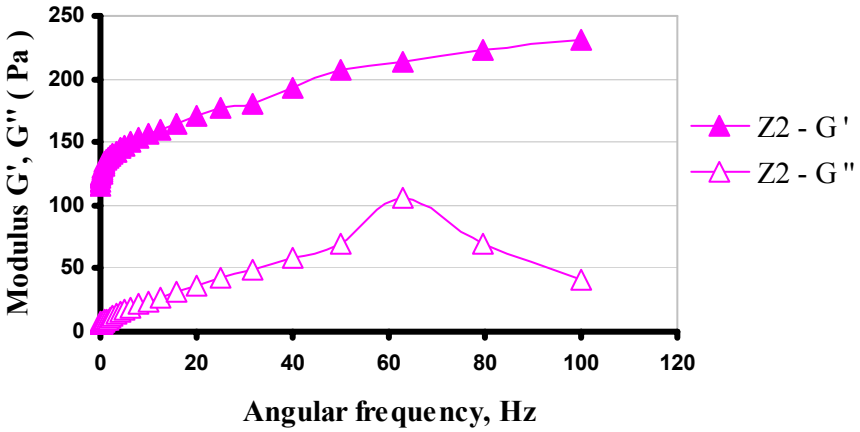

Figure 8. Dynamic mechanical spectra of Z2 mayonnaise sample

In Fig. 9 the G' increases from 111.5 Pa (0.1 Hz) to 178.2 Pa (39.81 Hz) then decreases to 75.7 Pa (100 Hz) and the Z3 sample has a bigger G''value than G'' value of other samples. The Z3 sample (although has the biggest β-glucan content) becomes gradually more fluid-like with a smaller network stability. In a protein stabilized oil-in-water emulsion containing polysaccharides, interaction between protein and polysaccharides can significantly affect the stability of the system [21,22,23].

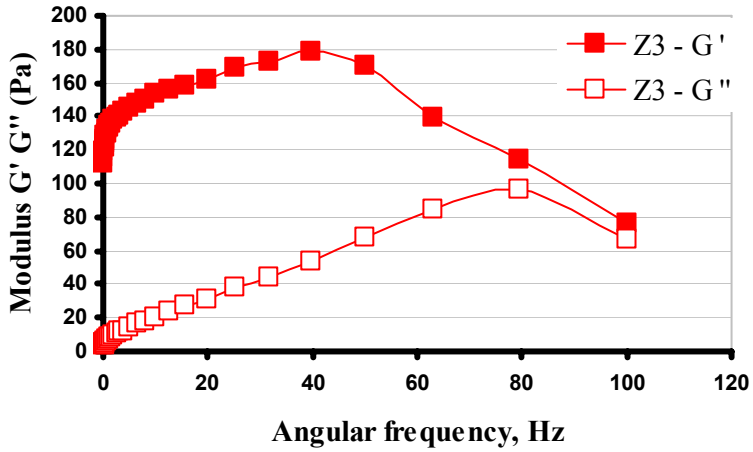

Figure 9. Dynamic mechanical spectra of Z3 mayonnaise sample

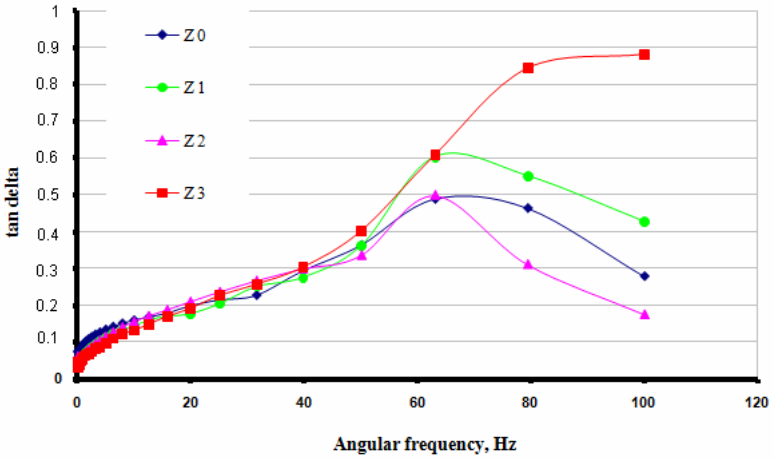

Figure 10. Loss tangents (tan δ) of mayonnaise samples

The rheological behavior study shows that the Z2 sample had the greatest performances concerning the emulsion stabilization capacities.

Conclusions

The spent brewer's yeast β-glucan can be used as a fat replacer in mayonnaise and as an emulsion stabilizer in the same time. The mayonnaises with 50% β-glucan substitution of oil have lower calorie and higher storage stability than mayonnaises without β-glucan. The β-glucan addition affects the least the color and the appearance of mayonnaise and the light mayonnaises obtained can be successfully used as dietary food.

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