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Rheological Properties of Low Fat Mayonnaise with Different Levels of Modified Wheat Bran

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ABSTRACT: Mayonnaise is probably one of the most widely used sauces worldwide. The oil content of traditionally mayonnaise is more than 65%. Fat has a role in creating viscosity, color and texture but might cause many diseases and disorders in human. In this study the influence of modified wheat bran as a fat replacer on the rheological properties of low fat mayonnaise was studied and compared to a blank sample containing starch. Low fat mayonnaise samples containing different amount of modified wheat bran (1, 2 and 3%) and blank were produced. The rheological analysis comprising the evaluation of flow properties and oscillatory tests were carried out by Rheometer. The results of flow curves showed that all the mayonnaise samples exhibited nonnewtonian, pseudoplastic behavior which fitted by Herschel-bulkley model and the factors related to this model were specified in the samples and blank. Storage and loss modulus obtained by the frequency sweep measurement classified mayonnaise samples into weak gels. The results showed that flow properties of mayonnaise samples depended on shear rate. The results indicated that separation between two phases of emulsion didn't occurred and all the samples were stable. The sample containing 1% modified wheat bran was behaving most similar to the blank and due to the best appropriate ratio between cellulose and starch was selected as the superior sample.

Keywords: *Flow Properties, Low Fat Mayonnaise, Modified Wheat Bran, Oscillatory Tests.*

Introduction

Mayonnaise is some one of the most widely used sauces in the world. This product is a mixture of egg, vinegar, oil and some other ingredients. Mayonnaise is a kind of semi-solid oil-in-water emulsion despite containing 70-80% fat (Depree & Savage, 2001). Fats are one of the essential components of the diet. Dietary fat provides essential fatty acids, precursors for prostaglandins and aids in the absorption of fat soluble vitamins (ADA, 2005).

In addition to nutrition, fat contributes key rheological properties and sensory characteristics. Fat contributes to flavor or the combined perception of mouth feel, taste, and aroma. Fat also contributes to creaminess, appearance, palatability, texture, and lubricity of foods and increases the feeling of satiety during meals (Akoh, 1998).

However fats and oils can cause a lot of diseases. High intake of total dietary fat is associated with increased risk for obesity, some type of cancer and possibly gallbladder disease. Epidemiologic, clinical and animal studies provide strong and consistent evidence for the relationship between saturated fat intake, high blood cholesterol and increased risk for coronary heart disease (calorie control council, 2006). Current dietary guidelines recommended limiting the

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total fat intake to < 30% of calories and saturated fats to <10% of total energy intake for the population as a whole (Ognean *et al.,* 2006).

Due to the risks of consuming too much oils and fats, people tend to reduce the amount of fat in their diet. Therefore replacing part of the fat with some other components which might play the role of fat in the foods but have fewer calories is essential.

Carbohydrate based replacers that are called fat mimetics are the largest and oldest group of fat replacers (Nancy, 1997). One of the carbohydrate based fat mimetics that can be used in the mayonnaise and other sauces is dietary fiber obtained from hulls and bran of cereals.

Up to now a lot of researches have done for producing low fat mayonnaise and salad dressings. Some fat mimetics such as modified starch (Murphy, 1999; Mun *et al.,* 2009), inulin (James, 1998), pectin (Pedersen & Christian, 1997) and microcrystalline cellulose (Chouard, 2005; Grodzka *et al.,* 2005), carrageenan (Trueck, 1997), some thickeners (Wendin *et al.,* 1997), whey protein isolate and low-methoxy pectin-based fat mimetics (Liu *et al.,* 2006), konjac flour (Choonhahirun, 2008), oat dextrin (Shen *et al.,* 2010) were generally used to stabilize the emulsion and to increase the viscosity of light mayonnaise.

Mayonnaise is nonnewtonian fluid and shows a yield stress, a pseudoplastic, a thixotropic behavior and time dependent characteristics (Barbosa-canovas & Ma, 1995; Goshawk & Binding, 1998; Mancini *et al*., 2002).

Various studies investigated the rheological characteristics of mayonnaise including flow properties and viscoelastisity of the product.

Barbosa-Canovas and Ma studied the flow and viscoelastic properties of mayonnaise at different oil and xanthan gum concentrations. They stated that the magnitude of elastic modulus and complex viscosity increased with the increase of oil or xanthan gum concentrations (Barbosa-Canovas & Ma, 1995).

In 2002, the rheological properties of mayonnaise containing alginates were studied. The results showed that Alginate concentration and molecular weight influenced mayonnaise functional properties (Mancini *et al.,* 2002).

Dolz et al investigated the effect of substituting part of modified starch with xanthan gum or locust bean gum in low fat mayonnaise, upon flow and thixotropic behavior. They reported that starch substitution with gums led to an increase in emulsions thixotropy (Dolz *et al.,* 2006).

In this paper the effect of different levels of modified wheat bran as a fat replacer on the rheological characteristics of mayonnaise (Flow properties and Oscillatory tests) were studied and compared to the blank sample which contains starch.

Materials and Methods

-Preparation of Mayonnaise

The type and amount of ingredients used in mayonnaise samples were formulated according to Behrooz Food Company (Aslanzadeh *et al.,* 2010). Before preparing samples of mayonnaise, concentrations of 1, 2 and 3% of modified wheat bran were hydrated in the water 48 hours individually and aqueous solution was pasteurized. Materials were used according to the conventional method for producing mayonnaise (Aslanzadeh *et al.,* 2010).

Mayonnaise samples containing different amounts of modified wheat bran and starch were coded in Table 1.

Table 1. Coding mayonnaise samples containing different concentrations of dietary fiber and starch

Sample Code	Dietary fiber (%)	Starch (%)
F.M.1	1	2.3
F.M.2	2	2.0
F.M.3	3	1.7
Blank	0	2.6

- Rheological Analysis

Flow properties and oscillatory tests were performed in a rheometer (Anton Paar Physica MCR300) to assess the effect of different concentrations of produced dietary fiber from wheat bran on the rheological characteristics of samples and compared with the blank.

The mayonnaise was analyzed using a parallel stainless steel plate having a diameter of 25 mm and a gap of 1 mm. All measurements were conducted at 25°C. Special care was taken to minimize emulsion softening when the sample was initially loaded on the plate. Excess sample protruding from the edge of the sensor was trimmed off carefully with a thin blade.

The mayonnaise flow properties were evaluated in shear rate range of 10^{-4}-10 1/s. The shear stress, viscosity, flow behavior index and thixotropy data were obtained by using the Herschel–Bulkley equation model as follows:

$$\tau = \tau_y + k \times \gamma^{\circ n}$$

Where τ is the shear stress (Pa), τ_y the yield stress (Pa), γ° the shear rate (1/s), k the consistency index (Pa s^n) and n the flow index.

In amplitude sweep test frequency was considered 1 Hz and applied strain rate was 0.01-100%. Linear viscoelastic region (γLVE) and G'_0 were determined. Frequency sweep was performed in a frequency range of 0.01-100 Hz, using strain values comprised in the linear viscoelastic region for each sample (0.3%). The recorded data included the components of shear modulus G' (storage modulus), viscous component G'' (loss modulus).

Results and Discussion

-Flow Properties

Changes in shear stress (τ) and viscosity (η) to shear rate (γ°) of mayonnaise samples are presented in Figure 1. The model-fitting flow equation parameters of different mayonnaise samples including *k*, the consistency coefficient (Pa. s^n) and *n*, the flow behavior index was determined (Table 2). After obtaining the regression equation according to this table it is specified that correlation coefficient (r^2) ranges from 0.94 to 0.98 indicating the results for this model.

- Oscillatory Tests

Diagram of amplitude sweep and rheological factors obtained from this test (G'_0 and γ_{LVE}) are shown in Figure 2 and Table 3 respectively.

The results of the frequency test for all samples are presented individually in Figure 3.

According to Figure 1, changes in viscosity to shear rate of samples are similar and viscosity decreases with increasing shear rate from 10^{-4} - 10 (1/s). Therefore all mayonnaise samples show pseudoplastic behavior that was reported earlier by researches (Barbosa-canovas & Ma, 1995; Juszczak *et al.*, 2003; Worrasinchai *et al.*, 2006).

In concentrated emulsions, the droplets are close enough together to interact with each other which may lead to the formation of a three-dimensional network of aggregated droplets. As the shear rate is increased, the hydrodynamic forces cause aggregates to become deformed and eventually disrupted which results in a reduction in the viscosity (McClements, 1999).

It can be seen F.M.3 sample has the lowest viscosity in many applied shear rates and viscosity of F.M.1 and F.M.2 are similar to the blank. In order to study this in detail, parameters obtained from Herschel–Bulkley model will be discussed.

It is clear from Table 2 that consistency coefficient (k) which is related to viscosity has the highest and closest score for F.M.1 sample with respect to the blank, but F.M.3 has the lowest value.

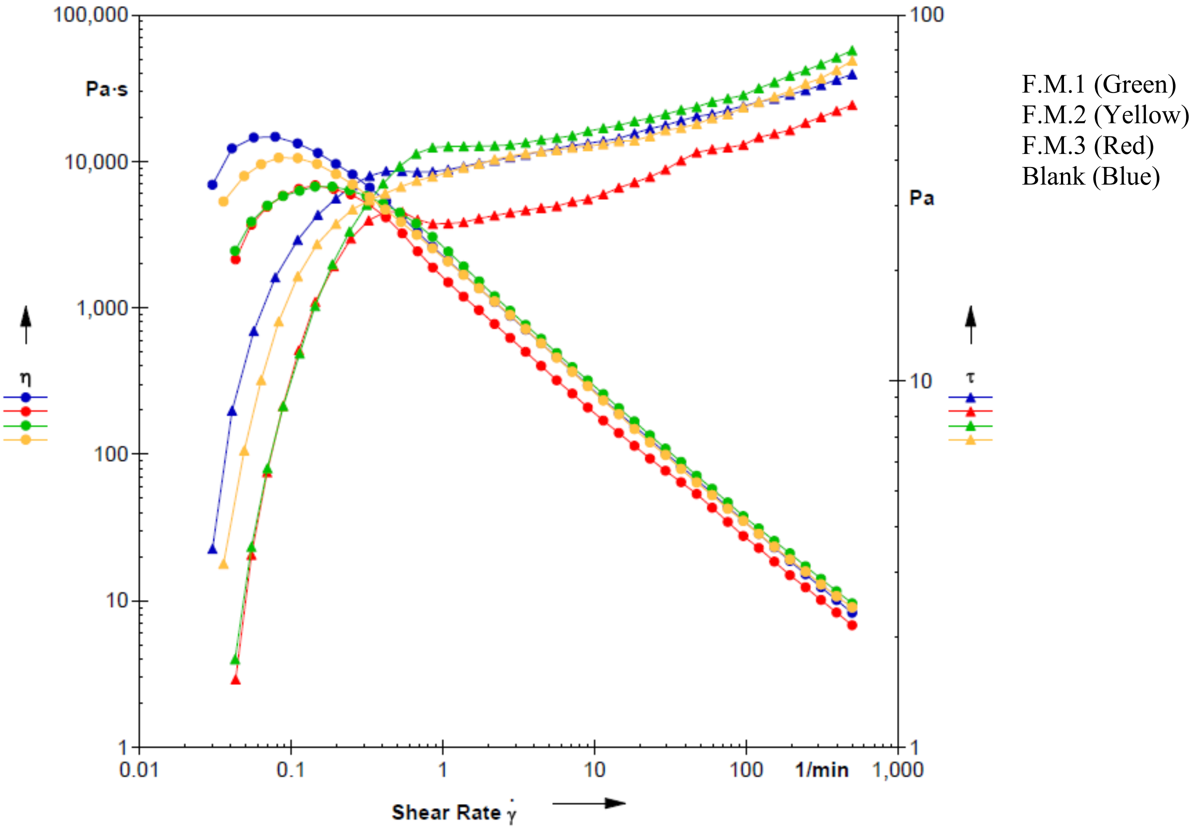


Fig. 1. Flow behaviour for the mayonnaise samples

Table 2. Model-fitting flow equation parameters of mayonnaise samples

Sample	K (Pa. s^n)	n	r^2
F.M.1	79.56	0.243	0.94
F.M.2	74.73	0.188	0.97
F.M.3	55.84	0.213	0.96
Blank	76.26	0.161	0.98

Table 3. Rheological factors obtained from amplitude sweep test

sample	G'_0	γ_{LVE} (%)
F.M.1	1070	0.785
F.M.2	637	0.298
F.M.3	423	0.483
Blank	240	1.27

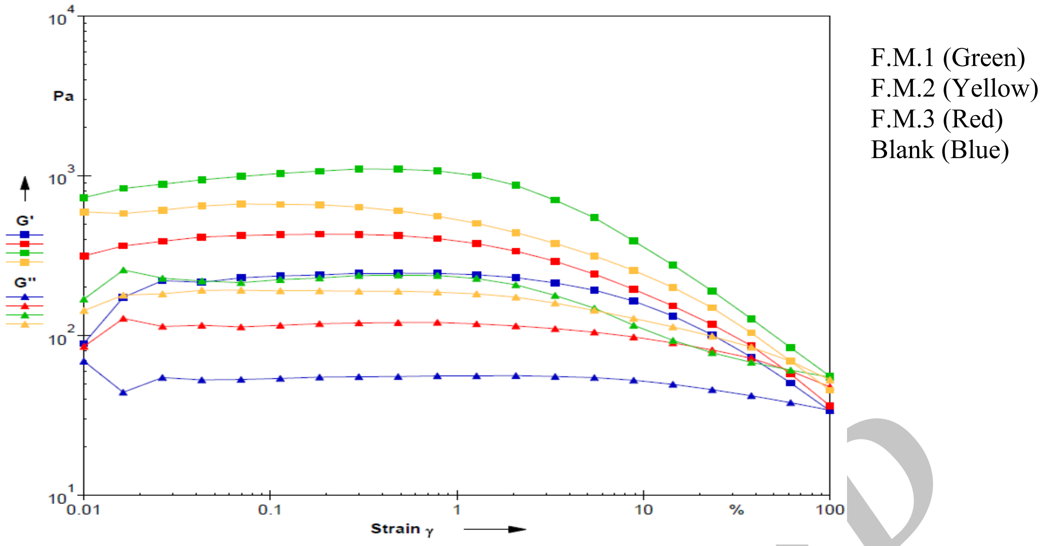
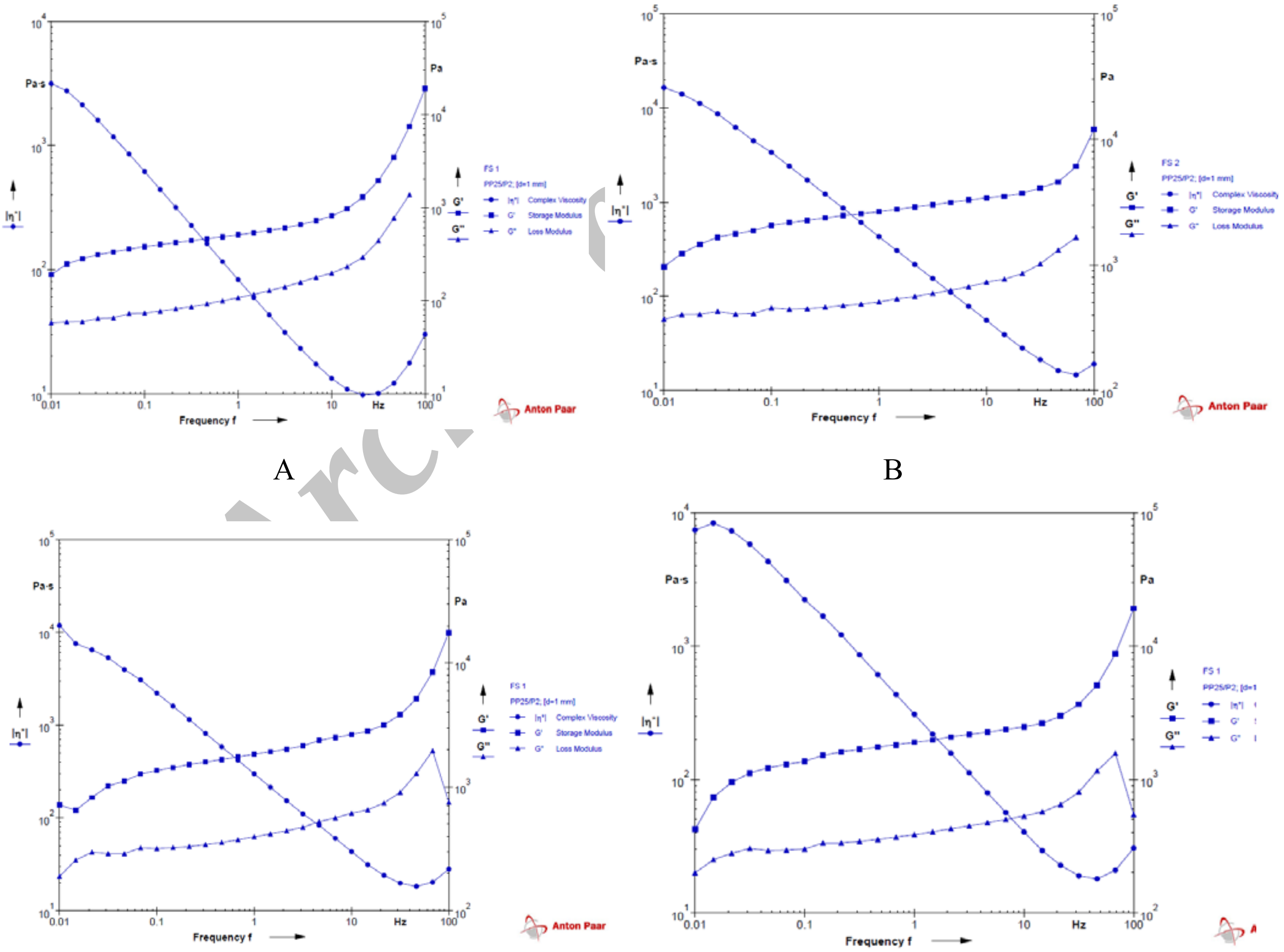


Fig. 2. Amplitude sweep for the mayonnaise samples



C

D

Fig. 3. Frequency sweep for the mayonnaise samples, A (F.M.1), B (F.M.2), C (F.M.3) and D (Blank)

Miyamoto et al. in 2009 studied interaction between cellulose and starch. They stated that the best appropriate ratio of the cellulose to the starch is 30-40%. Increasing the amount of fiber has negative impact on the viscosity and consistency (Miyamoto *et al.,* 2009). Therefore, in this research just F.M.1 sample ratio is suitable (43%) and among all samples has the greatest consistency. The ratio of F.M.2 and F.M.3 samples isn't ideal and *k* value decrease with increasing amounts of fiber.

In terms of flow behavior index (n) mayonnaises behaved as shear thinning fluids and *n* values were less than 1. These findings are in agreement with the results of other researchers (Barbosa-canovas & Ma, 1995; Juszczak *et al.,* 2003; Worrasinchai *et al.,* 2006; Liu *et al.,* 2007). Results showed that F.M.1 has maximum *n* value and the least pseudoplastic behavior.

According to the results obtained from amplitude sweep test, it is clear that G'_0 values describing the network strength of mayonnaise samples is in the range of 240-1070 (Pa). Greater values of G'_0 lead to more consistency of the product. Therefore, it becomes clear that among all the samples, F.M.1 has the maximum consistency. From F.M.1 to F.M.3 samples with increasing modified wheat bran in the formulation G'_0 has decreased. An explanation for this trend is the appropriate ratio of fiber to the starch. Another important point is that blank has the lowest G'_0 and the weakest network. It can be concluded that adding dietary fiber to mayonnaise samples improves their strength structures.

γ_{LVE} is the maximum strain that samples can tolerate in the linear viscoelastic region. Therefore, frequency test should be performed in the frequency range which is less than minimum γ_{LVE} obtained from amplitude sweep.

Dynamic oscillatory shear tests were used to characterize the viscoelastic properties of the mayonnaise samples containing different concentration of modified wheat bran and starch. The results from the oscillatory shear tests were expressed in terms of the elastic modulus (G') and loss modulus (G"). If G'>G", the material exhibits a solid like behavior; however, if G" > G', the material behaves like a liquid. Fig. 2 represent the dynamic mechanical spectra of the mayonnaise samples obtained by the frequency sweep measurement classified into that of weak gels because G' was larger than G". Thus it could be suggested that low fat mayonnaises are weak and gel-like, as is typical of dressings and emulsions.

Previous studies have also reported that mayonnaise samples exhibited weak gel-like characteristics in the frequency range of 0.1-10 Hz (Mancini *et al.,* 2002; Liu *et al.,* 2007; Mun *et al.,* 2009). A high storage modulus implies that higher stresses are necessary before the emulsion can flow. On the other hand, it also means that emulsion stability is enhanced in low stress situations. As a result, the possibility of any structural changes taking place during storage is reduced by using modified wheat bran.

Also in the frequency range tested, confluence between the G' and G" streams isn't observed. This result indicated that separation between two phases of emulsion didn't occurred and mayonnaise samples containing dietary fiber like to control were stable. Confluence between the G' and G" might have happened in control sample. Therefore, in frequencies less than 0.01, separation of two phases may be observed just in control.

Conclusion

From the results of this work, it can be concluded that flow properties of mayonnaise samples depended on shear rate. F.M.1 sample containing 1% modified wheat bran was behaving most similar to the blank. Due to the high amounts of fiber, some samples had a negative influence on the rheological characteristics. Therefore this sample was selected as the superior sample.

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