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ORIGINAL PAPER

Effects of Bacterial Cellulose as a Fat Replacer on Some Properties of Fat-Reduced Mayonnaise

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AYLIN AKOĞLU[1]*, IBRAHIM CAKIR[2], AYNUR GUL KARAHAN[3], M. LUTFU CAKMAKCI[4]
[1]Abant Izzet Baysal University, Department of Gastronomy and Culinary Arts, Bolu, Turkey
[2]Abant Izzet Baysal University, Faculty of Engineering and Architecture, Department of Food Engineering, Bolu, Turkey
[3]Süleyman Demirel University, Faculty of Engineering and Architecture, Department of Food Engineering, Isparta, Turkey
[4]Ankara University, Faculty of Engineering, Department of Food Engineering, Ankara, Turkey
**Address correspondence to: aylinakoglu@ibu.edu.tr*

Abstract

In the present study, the effects of bacterial cellulose on the sensory evaluation and rheological behavior of fat-reduced mayonnaise were examined. Oil content of samples was reduced from 75% to 60% and replaced by BC at levels of 0.25%, 0.50%, 0.75%, 1% and 2%. The pH of the control sample was significantly lower (P<0.05) than that of groups containing BC and the control sample had higher viscosity than the other groups. All samples were found to exhibit non-Newtonian pseudoplastic behavior. The results of sensory evaluation indicated that there was no significant difference (P<0.05) between groups in terms of smell, thickness, oiliness and aftertaste. BC could therefore be used as a fat replacer in the production of fat reduced mayonnaise.

Key words: Bacterial cellulose, fat replacer, mayonnaise, rheological behavior, sensory analysis, viscosity

1. Introduction

Mayonnaise is probably the most widely used and one of the oldest sauces in the world. It is a semi-solid solution that is manufactured with edible oils, egg yolks, salt, vinegar, thickening agents and flavoring materials. In the traditional production, these ingredients are carefully mixed to prevent separation of water and oil phases (MCCLEMENTS [1]; LIU & al. [2]). Commercial mayonnaise has mostly 70 - 80% fat content; and it is easily produced as low fat versions for conscious consumers. The "light" mayonnaise products contain about 36 % fat and starches, cellulose gel or other ingredients as the fat replacers which stimulate the texture of the mayonnaise. Light mayonnaise products can help adult consumers reduce their fat intake to recommended levels (MCCLEMENTS [1]; CHOONHAHIRUN [3]). Some fat replacers such as modified starch, xanthan gum, and pectin and carboxymethylcellulose soy milk which are used to prevent the stability of the emulsion and to increase the viscosity of light mayonnaise. In the last decade, production of reduced-calorie foods using water in oil in water (W/O/W) double emulsions is preferred to traditional methods (IZIDORO & al. [4]; NIKZADEA & al. [5]). Although W/O/W emulsions have lower oil content, the rheological properties of W/O/W emulsions were similar to those of a simple O/W emulsion with the same volume of the dispersed phase. Thus double emulsions could be used to reduce differences between traditional and light products (CINDIO & al. [6]).

Over the past decade, the production of low fat food products has increased dramatically due to adverse health effects associated with overconsumption of certain types of lipids (e.g., cholesterol and saturated fats). Several chronic diseases such as obesity, cardiovascular diseases, cancer related with dietary fat have created serious health problems for consumers. A lot of pressure was mounted on the food industry to reduce the amount of fat and other certain additives in the diet. However, fat influences the rheological properties and sensory characteristics such as flavor, appearance, texture, and shelf life of food products, and will be difficult to maintain the traditional product quality when preparing fat-reduced foods. It is important to be careful in choosing fat replacer in order to have a product with a texture close to that of the traditional product. Some biopolymers, such as gums, starches, and proteins are often added to fat-reduced products to provide some functional attributes (MURPHY [7]; IZIDORO & al. [4]; MUN & al. [8]).

A number of research have demonstrated that bacterial cellulose (BC) has important applications in a variety of food formulations because of its unique properties and structure that distinguish it from other forms of cellulose such as high polymer crystallinity, high degree of polymerization, high purity, high water absorption and retaining capacity (up to 700 times its dry weight), high tensile strength, and strong biological adaptability (HOLMES [9]; KHAN & al. [10]; HONG & al. [11]). BC was determined to be “generally recognized as safe” (GRAS) and accepted for by the Food and Drug Administration in 1992 (KHAN & al. [10]). In Asia, BC is used in baked goods, desserts, snacks, drinks and beverages as food ingredient that is a popular gelatinous and springy fiber. BC can maintain viscosity in food and retard glucose and bile acid diffusion effectively when it was used as a thickening agent (CHAU & al. [12]; ESA & al. [13]). BC is used in conjunction with other agents like sucrose and carboxymethylcellulose to improve the dispersion of the product. In addition to these, its potential food applications also include as a low-calorie additive, stabilizer and texture modifier (KHAN & al. [10]). Some fat replacers such as modified starch, inulin, pectin and microcrystalline cellulose, carrageenan, some thickeners were generally used to stabilize the emulsion in production of reduced fat mayonnaise (LIU & al. [2]; ALI & al. [14]). However information regarding the potential application of BC in replacing fat for the production of fat reduced mayonnaise is very scarce or not existing.The aim of this work was to investigate the effect of bacterial cellulose used as fat replacer on the sensory characteristics and rheological behavior of fat-reduced mayonnaise and to compare with a standard formulation.

2. Materials and methods

2.1. Materials

Bacterial cellulose used as fat replacer was produced by *Gluconacetobacter* sp. A6O2 isolated from vinegar sample and identified according to biochemical and 16s rRNA gene sequencing (KARAHAN & al. [15]). Other ingredients for the production of the mayonnaise such as vegetable oil, egg, vinegar, sugar and salt were all purchased from a local supermarket.

2.2. Production of bacterial cellulose

The bacterial strain *Gluconacetobacter* sp. A6O2 was grown on HS Broth medium (HESTRIN & al. [16]) with a following composition per liter: 20 g glucose, 5 g yeast extract, 5 g peptone, 2.7 g Na_2HPO_4, 1.5 g citric acid. The prepared 800 ml culture medium was poured into the sterilized stainless steel cooking tray with the size of 30x40x10 cm^3, inoculated with a 10% (v/v) cell suspension and incubated in static conditions at 28°C for 7 days. After incubation, the pellets were treated with 0.1 N NaOH solution at 80°C for 20 minutes to remove bacterial cells and medium components. The cellulose pellets were then rinsed with deionized water three times and purified cellulose was dried at 80°C in a vacuum oven for 8 h (BAE & al. [17]). Dry product was grinded to a 40 mesh particles by a laboratory mill (Retsch GE, USA) and used for mayonnaise production.

2.3. Preparation of mayonnaise

Samples of mayonnaise were prepared using the recipe given in Table 1. Oil content of mayonnaise samples was reduced from 75% to 60% and replaced by BC at levels of 0.25% (Mayonnaise 1; M1), 0.50% (Mayonnaise 2; M2), 0.75% (Mayonnaise 3; M3), 1% (Mayonnaise 4; M4) and 2% (Mayonnaise 5; M5) as fat replacer. The water phase was first prepared by mixing all of the ingredients and BC apart from the oil in a 1 L plastic beaker. The oil was then carefully mixed with the water phase and blended further for 2 minutes. The samples of mayonnaise were maintained in refrigerated condition at 4°C until the analyses were performed. Appearance of mayonnaise samples was shown in Figure 1.

Table 1. Recipe for mayonnaise samples

Ingredients	Control	M1	M2	M3	M4	M5
Vegetable oil (mL)	150	120	120	120	120	120
Egg yolk (mL)	40	40	40	40	40	40
Vinegar (mL)	12	12	12	12	12	12
Salt (g)	4	4	4	4	4	4
Sugar (g)	2	2	2	2	2	2
Water (ml)	-	30	30	30	30	30
Bacterial cellulose (g)	-	0.52	1.05	1.57	2.1	4.2
Bacterial cellulose (%)	0	0.25	0.50	0.75	1.0	2.0

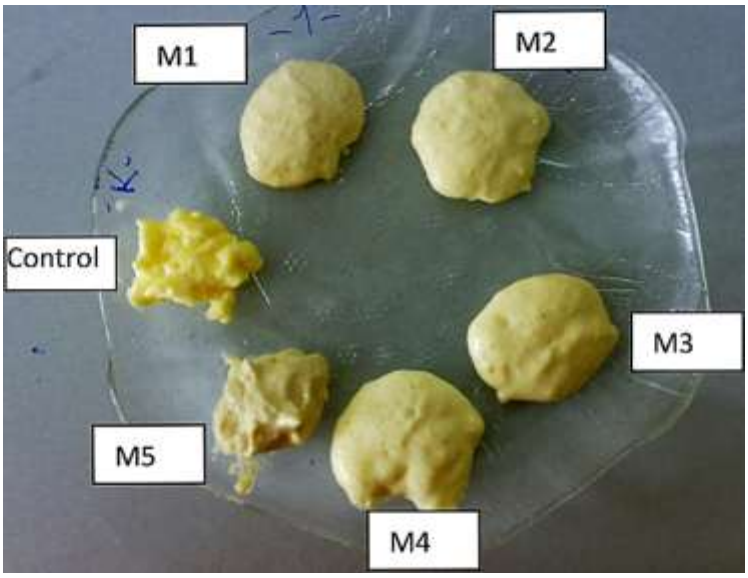

Figure 1. Appearance of mayonnaise samples

2.4. Evaluation of mayonnaise

The sample produced where subjected to the following analysis:

pH: Sample (10 g) was placed in a beaker and measured by using a pH-meter (Selecta, Spain).

Viscosity: The viscosity was measured using AND Vibro Viscometer SU–10 at stable vibration at 20–21ºC and 30 Hertz frequency.

Rheology analysis: The rheological measurements were performed in a rheometer (TA.AR 2000 EX, USA). The mayonnaise flow properties at 25°C was analysed using a paralel stainless steel plate having a diameter of 40 mm.

Sensory Evaluation: Sensory evaluation was conducted on the produced samples after 1-day storage at room temperature. The attributes selected were colour, smell, glossiness, thickness, oiliness and aftertaste, and they were measured using a ten-point scale by a group of 10 panelists. A rating scale linear structured (0 = dislike extremely to 10 = like extremely) was used to evaluate the intensities of perceptions of each sample. The panelists were first trained to understand the aforementioned parameters related to mayonnaise. The mayonnaise samples were presented to panelists in a completely randomized manner. Each mayonnaise was coded with a three-digit number. The tests were conducted at room temperature and water was provided between samples to cleanse the palate.

Statistical Analysis: Statistical treatment of the data was done by Duncan's multiple-comparison test using Statistical SPSS for Windows version 11.0.

3. Results and discussion

3.1. pH and viscosity

The result of the analysis of the pH and viscosity is being presented in Table 2. The result indicated that the pH is not affected by the amount of BC used in the samples as all samples have different pH. The buffering capacity of BC has not manifested in the results as widely acknowledged in the literature as the results are not consistent with various order of the use of BC. The pH of the mayonnaise samples ranged from 3.85 to 4.13 and was significantly higher ($P<0.05$) than that of the control samples. The result of the study conducted by PONS & al. [18] indicated that commercial mayonnaises had pH of 3.1–3.9. Although there is no significant difference with the reported values, this is likely to affect the taste of the samples at higher levels of BC.

Table 2. pH and viscosity of mayonnaise samples

	Control	M1	M2	M3	M4	M5
pH	3.85[a]	4.08[cd]	3.92[b]	4.04[c]	3.94[b]	4.13[d]
Viscosity (mPas)	8831.95[a]	636.55[b]	747.5[c]	832.35[d]	1232.3[e]	2649.25[f]

*Means in the same column with different letters are significantly different. Values in column with common letters are not different (P<0.05)

The result of viscosity determination indicated that although the control sample has a significantly higher value, the results shows that the viscosity increases with an increase in BC. The sample with the highest BC has a significantly higher viscosity value when compared with other samples. This is in conformity with the result of the research conducted by CHAU & al. [12] which revealed that BC can maintain viscosity in food and retard glucose and bile acid diffusion effectively when it was used as a thickening agent.

3.2. Rheological analysis

Results of viscosity were evaluated in detail with rheological analysis. The rheological behaviors of mayonnaise samples are shown in Figure 2. Shear stress versus shear rate curves showed the non-Newtonian behavior of mayonnaise samples.

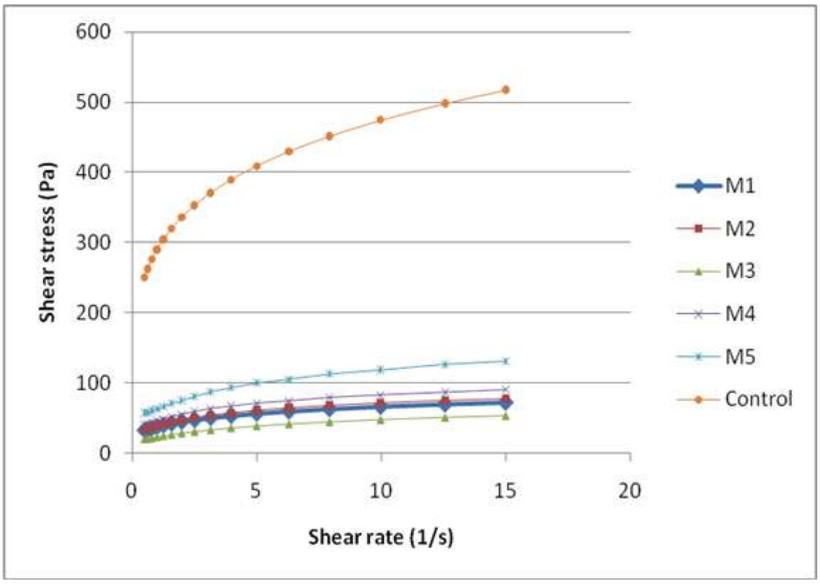

Figure 2. Flow curves of mayonnaise samples

Control sample showed higher values of shear stress with the increase of shear rate and this result can be related to the higher content of oil in the formulation (IZIDORO & al. [4]). According to typical viscosity curves are shown in Figure 3, control sample has higher viscosity than the other samples. However it has been revealed from the results of the study that the viscosity increases with an increase in the amount of BC. This suggests that BC used at higher levels can be very effective and to some extent helps in the replacing fat.

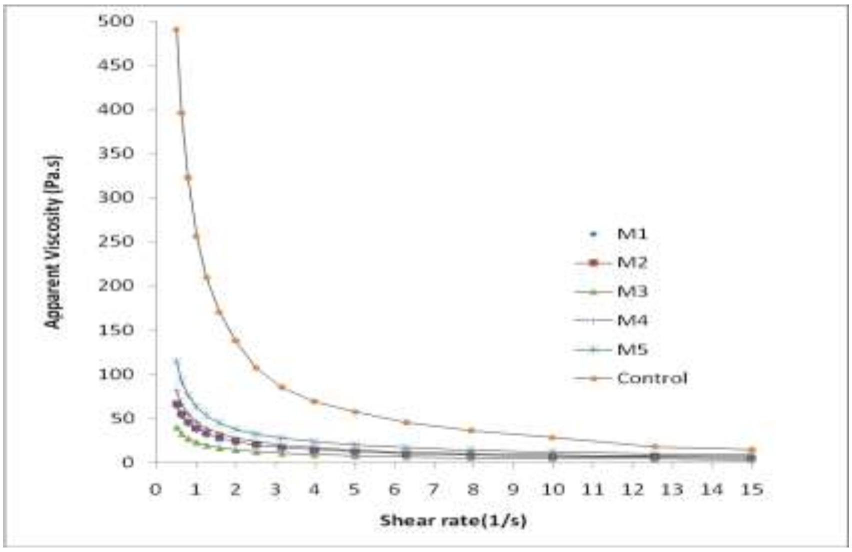

Figure 3. Viscosity changes at various shear rates

All samples showed non-Newtonian behavior since the viscosity of all the samples decreased when the shear rate was increased (PAREDE & al. [19]). Mayonnaises are known to exhibit pseudoplastic behavior, with a significant decrease in the viscosity of the samples as the shear rate increases. This process can be associated with flocculation-deflocculation of the oil droplets in the aqueous continuous phase. As the shear rate increases, the reaction shifts on the deflocculation and hence the apparent viscosity decreases (CHEUNG & al. [20]). Flow properties were examined, it was shown that all mayonnaise samples showed thixotropic shear thinning behavior over the whole range of shear rate (0–150 1/s). The thixotropic characteristics of mayonnaise in the shear rate range of 0–200 1/s were reported by STERN &

al. [21]). As the shear rate is increased, the hydrodynamic forces cause progressive deformation and disruption of the aggregated particles, which results in resistance to flow and a reduction in the viscosity (LIU & al. [2]; MUN & al. [8]).

3.3. Sensory analysis

The results of sensory analyses are given in Table 3. All of the samples showed no significant difference (P>0.05) between the sample in terms of smell, thickness, oiliness and aftertaste. This indicates that addition of BC while effectively replace fat in mayonnaise does not affect these attributes and consumer senses fat reduced mayonnaise as traditional mayonnaise. However control sample has higher value than M1, M2, M3, M4 in terms of oiliness and aftertaste, although these differences are not statistically significant (P>0.05). Additionally, the use of BC is likely to affect colour and glossiness scores as the showed in the result with all samples but M4 having lower scores than the control sample. This has been confirmed by KARAS & al. [22] whose research indicated that color of light mayonnaise is too pale and dense due to addition of thickening agents.

Table 3. Sensory attributes of mayonnaise samples

	Control	M1	M2	M3	M4	M5
Colour	6.7 ± 2.1^{ab}	5.3 ± 0.6^{b}	7.0 ± 1.0^{ab}	7.0 ± 1.0^{ab}	8.3 ± 1.5^{a}	5.0 ± 1.0^{b}
Smelling	7.3 ± 2.1^{a}	6.0 ± 1.7^{a}	7.7 ± 1.5^{a}	6.7 ± 1.5^{a}	7.3 ± 1.2^{a}	6.0 ± 1.7^{a}
Glossiness	8.7 ± 0.6^{a}	6.3 ± 0.6^{b}	7.3 ± 0.6^{ab}	7.7 ± 0.6^{ab}	9.0 ± 1.0^{a}	6.3 ± 2.3^{b}
Thickness	7.3 ± 2.1^{a}	7.0 ± 1.0^{a}	7.7 ± 0.6^{a}	7.7 ± 1.5^{a}	7.3 ± 1.2^{a}	6.7 ± 1.2^{a}
Oiliness	8.7 ± 0.6^{a}	7.7 ± 0.6^{a}	7.7 ± 0.6^{a}	7.0 ± 1.7^{a}	7.0 ± 1.7^{a}	8.3 ± 0.6^{a}
Aftertaste	8.0 ± 1.0^{a}	7.3 ± 0.6^{a}	7.7 ± 1.2^{a}	7.0 ± 2.0^{a}	7.3 ± 2.1^{a}	7.3 ± 2.1^{a}

*Means in the same column with different letters are significantly different.(P<0.05).

4. Conclusions

Although, there are differences in the pH and viscosity between the samples and the control, it appears that physical properties such as viscosity and pH do not influence sensory properties of fat-reduced mayonnaise. There is no significant difference in most of the sensory attributes tested except of colour and glossiness. It is therefore recommended that BC could be used as fat replacer for the production of fat-reduced mayonnaise. Additionally, in order to obtain more clear results, some analysis such as composition analysis, texture analysis and particle size measurement should be done in much more details.

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