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GELATIN FROM BONES OF BIGHEAD CARP AS A FAT REPLACER ON PHYSICOCHEMICAL AND SENSORY PROPERTIES OF LOW-FAT MAYONNAISE

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ABSTRACT

The objective of this study was to produce a low-fat mayonnaise containing gelatin from bighead carp by-products as a fat replacer. Low-fat mayonnaise samples were made by substituting the oil with fish gelatin at 0% (T0), 10% (T10), 25% (T25), and 40% (T40). Also, some physiochemical properties and sensory qualities of reduced fat mayonnaises were investigated. T40 had the lowest caloric value while, the lowest whiteness was measured in T40 (46.12%) compared to the control group (79.58%) ($P<0.05$). The reduced fat in T40 samples presented high values of texture properties as well as the highest hardness, adhesiveness and resilience ($P<0.05$). Also, the highest level of emulsion stability was reached in T40 treatment ($P<0.05$). The highest and the lowest titratable acidity were recorded in T0 (0.85%) and T40 (0.60%) treatments, respectively. The results of sensory evaluation in term of overall acceptability showed that T40 had the highest score compared to other treatments. This study revealed a good potential usage of the fish gelatin as a fat mimetic in low-fat mayonnaise formulation up to 40%.

Keywords: Bighead carp, Fat replacer, Fish gelatin, Mayonnaise, Texture

INTRODUCTION

Gelatin is a unique hydrocolloid with a mixture of peptides/proteins and produced by partial hydrolysis of collagen from the skin, bones, and connective tissues (Karim and Bhat, 2009). Recently, worldwide demand for gelatin in a vast range of applications in a food industry, hygienic products, cosmetics, biodegradable packaging and pharmaceutical products (Jellouli *et al*., 2011) is increased, and its market demand is estimated about 326.000 tons (Wang *et al*., 2014). In the recent years, interest in using of fish gelatin instead of mammalians sources is highly increased due to some social and religion conflicts (Badii and Howell, 2006) as well as transmission disease prevention (Gómez-Guillén *et al*., 2009). Meanwhile, by-products obtained from fish processing factories such as fish skin and bone could be considered as a valuable source of producing gelatin.
Bighead carp (*Hypophthalmichthys nobilis*) is one of the commercial freshwater fish species which is the most exploited farm-raised fish in earthen ponds in Iran and Asia. Aquaculture production of bighead carp increased rapidly from 3219 tons in 1978 to 3250000 tons in 2014, representing 39.2% of the total fish production (FAO, 2016). This fish has a large head compared to the body size, and this is why the fish price gets lower than other cyprinid species e.g. common carp, grass carp and silver carp. There is an opportunity to alter this substantial amount of waste materials to gelatin. In other words, fish waste can be treated and converted to various value-added products with high biological values instead of being discarded and causes potential negative environmental impacts (Mahdabi and Hosseini Shekarabi, 2018). However, no study has been carried out to assess the potential use of fish bones in low-fat mayonnaise and/or other food applications.
Mayonnaise is oil-in-water (O/W) emulsions and traditionally produced by emulsifying materials like egg yolk and contains salt, vinegar, constancy agents and flavored materials (Mun *et al*., 2009; Pulingundla *et al*., 2015). Generally, mayonnaise considered as a high fat and calorie levels due to high amount of oil (>65%) (Su *et al*., 2010), and leads it unhealthy and weight gaining foodstuff especially by increasing in cholesterols and saturated oils in the consumers (Pulingundla *et al*., 2015). Therefore, development of defat or reduced fat mayonnaise is one of the most important strategies for investigators to find an appropriate fat mimics (Worrasinchai *et al*., 2006; Lorenzo *et al*., 2008; Nikzadeh *et al*., 2012). Hydrocolloids, particularly maltodextrin (Saavedra-Leos *et al*., 2015) and modified starches improved rheological properties and viscosity of low-fat food products (Weber *et al*., 2009). Replacing oils with hydrocolloids in O/W emulsions leading to increasing in heat stability (Lorenzo *et al*., 2008), improving texture and mouth feeling (Pszczola, 1999). The benefits of replacing oil with fish gelatin is antioxidant and antibacterial properties of fish gelatin biopeptide, which prevent bacteria growth during storage period (Triawati *et al*., 2016).
The most important characteristics of fish gelatin can be classified into two groups: i) properties associated with texturizing, thickening, and water capacity, and ii) properties relevant to emulsion, foam formation, stabilization, adhesion, cohesion, and foam forming capacity. Likewise, use of gelatin as a fat substitute is thought to be related to its ability to simulate and mimic the sensory properties of fats (Badii and Howell, 2006; Karim and Bhat, 2009; Wang *et al*., 2014). Many researches formulated gelatin from different sources as a stabilizer in meat products during storage (Cheng *et al*., 2014), producing low-fat yoghourt (Behnia *et al*., 2013), improving creamy mouth-feel and viscosity of feeling in low-fat ice cream (Lim *et al*., 2013), low-fat whipped cream (Sajedi *et al*., 2014), improving textural properties of low-fat mascarpone cheese (Carvalho *et al*., 2015), and low-fat fat spread (Cheng *et al*., 2008).
The aim of this study was to evaluate the effects of bighead carp gelatin from the head bones on some physiochemical properties and sensory qualities of low-fat mayonnaise.

MATERIALS AND METHODS

Extraction of gelatin from bighead carp head bones

Bighead carp heads were prepared from a local market (Tehran, Iran) and stored at -20°C until used. The bones were allowed to completely thaw at room temperature for 4 h prior to extraction. Gelatin from fish heads was prepared following the procedure described by Muyonga *et al*. (2004) with some modifications. Briefly, the thawed bone was first thoroughly cleaned with a knife and rinsed with plenty of water to eliminate muscle tissue and then degreased by soaking in 0.1 N sodium hydroxide at a ratio (bone-to-NaOH) of 1:1 (w/v) at 4°C for 4 h followed by several washing with running tap water until the pH reached about 6. The degreased bones were then demineralized using 0.4 N HCl at ambient temperature for 9 days until the bones became soft and transparent. In this case, the acidulation solution was changed at 3 day intervals. The leached bones were washed with running tap water until the wash water pH was above 4 and reached near 6. The pretreated materials were transferred to beakers and the gelatin was extracted in water baths (Memmert, Germany) at 70°C for 2 h. After this stage, the mixture was subjected to a sterilization process by autoclaving at 121 °C, 100% RH and 1 atm. The extract was filtered through two layers of cheesecloth and dried at 60°C for 24 h in a forced-air oven (Binder, Germany) until the moisture was reached less than 10 g water per 100 g of gelatin. The brittle sheets of gelatin were broken into small pieces and milled (IKA Works A11 Basic Mill, Germany) into powder (particle size 1 mm, 90% mesh passed). The dried gelatin powder was stored in air-tight polyethylene bags and kept in a cool and dry place.

Preparation of aqueous phase

Aqueous phase solution were prepared by dispersing of 10 g fish gelatin and 2 g maltodextrin (food grade, DE<20, Dalian Future International Co., China) powders in double distilled water with 2 ml skimmed milk (Mihan, Tehran) and stirring for 10 min at room temperature . The aqueous phase were stored at 4°C prior to further usage. Sodium azide (Sigma-Aldrich, UK) at 0.02% (w/w) was added to the stock solutions to prevent microbial growth (Wu and McClements, 2015).

Preparation of low-fat mayonnaise

Mayonnaise samples were prepared as described previously by Liu *et al*. (2007) with some modifications. The recipes of mayonnaise as control and low-fat samples are shown in Table 1. First, egg yolk and vinegar were mixed in a glass beaker and blended using a KitchenAid mixer (K4555, St. Joseph, Michigan, USA) at medium speed for 10 s in order to provide consistent and reliable samples. Then, prepared aqueous phase was added and stirred at high speed for 1 min. Finally, the sunflower oil was added slowly (200 mL/min flow rate), and all the ingredients were stirred at high speed for 2 min. Mayonnaises were transferred to a plastic sealed jars and protected against light and moisture, then stored at refrigerator (4°C) over the night until further analysis.

Table 1 Ingredients of full-fat and low-fat mayonnaise samples by fish gelatin from bighead carp bones.

	T0*	T10**	T25***	T40****
Sunflower oil	70	63	52.5	42
Egg yolk	12	12	12	12
Gelatin (aqueous phase)	0	7	17.5	28
Vinegar	12	12	12	12
Mustard	0.3	0.3	0.3	0.3
Sugar	0.5	0.5	0.5	0.5
Distilled water	5.2	5.2	5.2	5.2

* Full-fat mayonnaise.

** Reduced-fat mayonnaise in which sunflower oil replaced by fish gelatin aqueous phase at the level of 10 wt% (when 10wt% of fish gelatin in aqueous phase was added).

*** Reduced-fat mayonnaise in which sunflower oil replaced by fish gelatin aqueous phase at the level of 25 wt% (when 25% of fish gelatin in aqueous phase was added).

**** Reduced-fat mayonnaise in which sunflower oil replaced by fish gelatin aqueous phase at the level of 40 wt% (when 40wt% of fish gelatin in aqueous phase was added).

Approximate composition and caloric values

Proximate composition namely, moisture, lipid, ash and protein were determined according to AOAC (2000) method. Also, fat content was measured by Bligh and Dyer (1959) method. Carbohydrate level was determined by subtracting total percent values of moisture, protein, fat, and ash from 100.
The caloric value (kcal/100 g) for each mayonnaise samples was calculated by following formula:
Total calorie value=(protein×4.02)+(Lipid×9)+(Carbohydrate×3.87)

Measurement of pH

The pH was determined by weighing 5 g of mayonnaise and homogenizing in 45 mL distilled water in a mixer (IKA Ultra-Turrax T25 basic homogenizer, Germany) at room temperature (25ºC) for 1 min. The pH of each slurry was determined with a digital pH meter (Model 827, Metrohm, Switzerland).

Emulsion stability measurement

The emulsion stability of mayonnaise was measured following a method of Bortnowska and Makiewicz (2006). Fifteen g (F0) of each sample was transferred to test tubes (internal diameter 15mm, height 125mm) and then tightly sealed with plastic caps and stored in the oven at 50◦C for 48 h. Heated samples were centrifuged for 10 min at 2500 ×rpm to remove the top oil layer. The weight of the precipitated fraction (F1) was measured, and the emulsion stability was calculated as follows:

Emulsion stability (%)= F1/F0 ×100

where F1 is a precipitated fraction (g) and F0 is an entire weight (g).

Titratable acidity

Titratable acidity (TA) was determined by titration of 10 g mayonnaise to pH 8 with 0.1N NaOH using a digital pH meter (827 pH lab, Metrohm, Swiss) at room temperature and results were converted to percentage of acetic acid according to the following formula (Abu-Salem and Abu-Arrab, 2008):

$$TA\ (\%) = (0.006\ a/b) \times 100$$

Where a is the volume of used NaOH (ml) and b is the sample weight (g).

Color determination

Mayonnaise samples were measured for color in the L*, a*, b* system where (+a) is the red, (-a) is the green, (+b) is the yellow, and (-b) is the blue directions using a Hunter lab digital colorimeter (Colorflex EZ, Hunterlab, Virginia, USA). A fixed amount of mayonnaise was poured into the measurement cup and whiteness index was calculated using the following formula (Chaijan and Undeland, 2015):
Whiteness %= 100-$[(100-L^{*2})+a^{*2}+b^{*2})]^{1/2}$

Texture profile analysis

Texture properties of all treatments were evaluated at room temperature using a Texture Analyzer (CT3, Brookfield, USA) equipped with a cylindrical probe (42 mm diameter). The sample was filled into an acrylic container (42 mm internal diameter and 55 height) in a depth of 30 mm. The test speed was fixed at 1.00 mm/s with a test distance of 15 mm, and upon compression the disc was returned to the initial starting point. From the resulting of force–time curve, firmness (g), resilience, adhesive force (g) and consistency (g/s) were calculated.

Sensory evaluation

Sensory evaluation of the mayonnaise samples were conducted throughout the one-day refrigerated storage. The sensory panel consisted of 8 expert staff members (four men and four women, ages 26-35) of Razi Complex Laboratory who had been selected according to International Organization for Standardization (ISO) and familiar with hedonic scale method. All sample observations were conducted according to recommendations described in ISO 13299:2003 guidelines. Samples for testing were taken out of the refrigerator and allowed to stand at ambient temperature prior to preparation. About 10 g of each sample was placed in a polypropylene container which was labeled with a three-digit random number. Also, the sample presentation order was randomized. Four sensory attributes were evaluated (flavor, texture, color and overall palatability) using a 5- point hedonic scale where 5= extremely excellent and 1=extremely poor.

Statistical analysis

All physicochemical experiments were replicated three times in a completely randomized factorial design. A one-way analysis of variance (ANOVA) was conducted. When a significant main effect was detected, the means were separated with the post-hoc Tukey's test. The predetermined acceptable level of probability was 5% (P<0.05) for all comparisons. The Kruskal-Wallis test was used to find out significant differences for the sensory attributes as a non-parametric analysis of variance at a 5% level of significance. All analysis was performed using SPSS software (v20.0 for Windows).

RESULTS

Chemical composition and caloric values

The approximate composition of dried gelatin powder derived from bighead carp bones are consisted of 95.08±0.021% protein, 1.59±0.014% lipid and 3.41±0.014% ash in dry basis. Also, the chemical composition and caloric values of the low-fat mayonnaise samples are listed in Table 2. There were no significant (P>0.05) difference between T25 and T40 samples in ash content, while carbohydrate content slightly increased with increasing in level of fat substitution. The full-fat mayonnaise (T0) had higher (P<0.05) lipid and caloric contents than the low-fat mayonnaise samples.

Table 2 Chemical composition and caloric contents of reduced fat mayonnaise samples by fish gelatin from bighead carp bones

Treatments	Protein (%)	Lipid (%)	Moisture (%)	Ash (%)	Carbohydrate (%)	Calorie (kcal/100)
T0	2.38±0.014^{d}	77.99±0.014^{a}	18.40±0.014^{d}	1.23±0.014^{d}	1.23±0.014^{c}	716±0.014^{a}
T10	3.60±0.014^{c}	64.63±0.53^{b}	29.41±0.021^{c}	0.88±0.014^{c}	2.37±0.523^{b}	605.51±2.737^{b}
T25	6.50±0.014^{b}	52.5±0.707^{c}	36.23±0.014^{b}	1.11±0.084^{b}	4.77±0.679^{a}	517.58±3.592^{c}
T40	9.21±0.269^{a}	41.50±0.700^{d}	44.34±0.028^{a}	1.09±0.094^{b}	4.95±0.467^{a}	430.14±3.422^{d}

Means with different letters in the same column are significantly different (n=3, P<0.05).

Total acidity and pH

The pH values of the control and low-fat mayonnaises with different the fish gelatin ratios after a day storage at room temperature are shown in Table 3. pH value significantly reached the maximum value in T40 sample, while no significant different from other trials was seen.

As shown in Table 3, increasing in replacing of the oil with fish gelatin resulted in lower acidity value of the low-fat mayonnaise samples.

Table 3 Changes in pH and acidity of reduced fat mayonnaise samples by fish gelatin from bighead carp bones

	T0	T10	T25	T40
pH	3.93±0.014^{a}	4.055±0.021^{a}	4.14±0.014^{a}	4.485±0.092^{a}
Acetic acid (%)	0.85±0.106^{a}	0.76±0.061^{b}	0.71±0.078^{c}	0.060±0.025^{d}

Means with different letters in the same row are significantly different (n=3, P<0.05).

Emulsion stability

Figure 1 illustrates the emulsion stability of control (T0) and low-fat mayonnaise samples. The T10 and T25 samples exhibited the lowest stability and are fairly look like commercial mayonnaises available in the markets, however both control (T0) and T40 trials had the highest emulsion stability with no significant different (Figure 1).

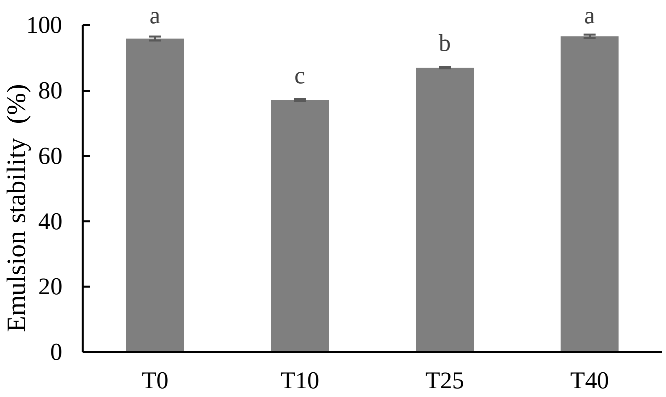

Figure 1 Emulsion stability of reduced fat mayonnaise samples by fish gelatin from bighead carp bones. Full-fat mayonnaise (T0) and low-fat mayonnaises by replacing oil at 10% (T10); 25% (T25) and 40% (T40) by fish gelatin. Bars with the different letters are significantly different (n=3, P<0.05).

Color of mayonnaise

The color coordinate values of the T0 (control) and low-fat mayonnaise samples with the different fish gelatin at desired rations after storage for one day at the room temperature are shown in Table 4. The highest L* value was obtained in full-fat sample compared to low-fat samples.

Table 4 Changes of color parameters of reduced fat mayonnaise samples by fish gelatin from bighead carp bones.

Samples	L*	a*	b*	Whiteness
T0	87.6±0.007^{a}	4.51±0.028^{b}	15.59±0.001^{d}	79.58±0.002^{a}
T10	81.19±0.092^{b}	5.85±0.007^{a}	20.59±0.057^{c}	71.65±0.018^{b}
T25	81.77±0.042^{b}	4.28±0.078^{c}	21.67±0.028^{b}	71.36±0.060^{b}
T40	80.69±0.069^{c}	4.12±0.014^{d}	26.05±0.028^{a}	67.31±0.017^{c}

Means with different letters in the same column are significantly different (n=3, P<0.05).

Textural properties

Table 5 shows some texture attributes of the low-fat mayonnaise sample prepared. The low-fat samples had higher textural characterizations in comparison to control ones. The firmness of the low-fat samples increased by increasing in the level of fat substituting and the lowest value was obtained in control ones. Low-fat samples revealed more adhesiveness values, particularly the highest value was observed in T40 (Table 5).

Table 5 Textural properties of reduced fat mayonnaise samples by fish gelatin from bighead carp bones.

Texture	Firmness (g)	Consistency (g/s)	Resilience	Adhesive force (g)
T0	2412.25±252.382^{c}	22.25±2.623^{c}	0.74±0.007^{b}	99.50±9.192^{d}
T10	2064.75±86.621^{c}	22.77±3.111^{c}	0.74±0.035^{b}	173.75±3.889^{c}
T25	2700.25±31.466^{b}	25.77±0.742^{b}	0.77±0.028^{a}	281.75±15.203^{b}
T40	2958.75±71.064^{a}	28.02±1.697^{a}	0.78±0.014^{a}	313.50±42.426^{a}

Means with different letters in the same column are significantly different (n=3, P<0.05).

Sensory evaluation

Sensory evaluation scores of low-fat mayonnaise samples are shown in Table 6. The appearance and odor scores are significantly (P<0.05) improved with increasing the replacement level of fish gelatin. Color of the T40 sample was evaluated as too faint. On the other hand, the color score were markedly decreased by increasing the fish gelatin replacement levels. T25 and T40 samples showed no significant (P>0.05) differences in texture scores from the T0 (Full-fat), whereas the T10 sample gave lower score for these attributes.

Table 6 Sensory evaluation of reduced fat mayonnaise samples by fish gelatin from bighead carp bones.

Treatments	Appearance	Color	Odor	Texture	Consistency	Total acceptance
T0	3.22±0.972^{bc}	4.67±0.707^{a}	3.33±0.707^{c}	4.11±0.782^{a}	3.56±0.726^{a}	3.33±0.707^{b}
T10	3.00±0.816^{c}	4.30±0.823^{a}	3.70±0.823^{b}	3.40±0.516^{b}	3.40±0.516^{b}	3.00±0.919^{c}
T25	4.20±0.632^{b}	3.40±0.843^{ab}	3.40±0.823^{b}	3.70±0.949^{a}	3.50±0.850^{a}	3.80±0.919^{a}
T40	4.40±0.699^{a}	3.00±0.816^{b}	4.50±0.707^{a}	4.10±0.738^{a}	3.90±0.944^{a}	4.10±0.738^{a}

Means with different letters in the same row are significantly different (n=12, P<0.05).

DISCUSSION

In this study, low-fat mayonnaise samples can be stabilized by using fish gelatin as a fat replacer, and the physicochemical properties can be improved. Proper emulsion stability and sensory properties were obtained at 40% of oil replacement with fish gelatin from bones of bighead carp.

The results showed that the reduction in lipid content could be attributed to the substitution of oil in full-fat mayonnaise with hydrocolloids in low-fat mayonnaise (Akoh, 1998). Also, the fish gelatin in aqueous form enhances texture of the low-fat mayonnaise due to more dense gel structure in O/W emulsion. Protein content in full-fat samples were much lower than low-fat samples due to higher content of crude protein of fish gelatin. The caloric values of the low-fat samples were significantly reduced, because fish gelatin is main component of aqueous phase as fat replacer, and maltodextrin in the aqueous phase mixture is non-caloric.

The pH values in this research showed no significantly differences between full-fat and low-fat samples, however 40% of oil replacement with fish gelatin sample was significantly more pH, this could be explained by dilution of acetic acid rest remaining in the low-fat samples (Worrasinchai *et al*., 2006; Hathcox *et al*., 1995). Amin *et al*. (2014) similarly reported that increasing the level of fat substitution with gums (xanthan and guar gums) in mayonnaise formulations resulted in increases in the pH values due to dilution of acetic acid in the aqueous phase of the low-fat samples. Raford and Board (1993) and Smittle (1997) suggested that pH of mayonnaise should be 4.1 or less to maintain product free from microorganism particularly from Salmonella sp. The pH values in this study was microbiological safety according to the pH ranged from 3.93 to 4.48.

Acidity is one the most important quality parameters for assessing spoilage rate of mayonnaise and desired total acidity was reported 0.7-1.2% acetic acid (Mihov *et al*., 2012). If the finished product is lower than this range, the risk of microbial growth greatly increase and also resulted in sour taste (Johari *et al*., 2015). The highest titratable acidy were observed in control sample (T0), whereas the low-fat samples, particularly at 40% of oil replacement with fish gelatin had the lowest acidity index. The reason of increasing in titratable acidity is probably non-enzymatic oxidation (Gomez *et al*., 2016) and greater acidity value was observed in control samples, which indicated the beginning of lipids decomposition and formation of free fatty acids (Silva *et al*., 2010). In agreement with the results, Abou-Zeid *et al*. (2013) reported that full-fat mayonnaise had a significantly higher acidity value than low-fat samples. Increasing in titratable acidity value could be mostly related to activity of acid tolerant microorganisms such as LABs (lactic acid bacteria) due to their hydrolytic and oxidative enzymes activities.

Emulsion stability characteristic of a mayonnaise is highly depend on oil and egg yolk concentration, mixing technique, and temperature (Harrison and Cunningham, 1985; Song *et al*., 2007). In this study, increasing in fish gelatin concentration caused the emulsion stability more stable. O/W emulsion stability of low-fat mayonnaises might be adversely affected by creaminess, flocculation, coagulation and phase diversion due to low content of oil in the formulation (Mun *et al*., 2009). For instance, in full-fat mayonnaise creaminess is not typically observed, because the oil droplets in these systems are enough close together. Therefore, when the fat level is decreased in mayonnaise, a thickener agent should be added to aqueous phase to reduce creaminess. In this case, replacement of oil with gelatin in low-fat mayonnaise can act as an emulsifier agents in improving of the viscosity features and become more stable due to decrease falling oil droplet movements (Manoj *et al*., 1998; Manoj *et al*., 2000).

In this research we demonstrated that the reduction of emulsion stability with decreasing in gelatin content probably due to weakening in three-dimensional network structure (McClements, 2006). Also, fish gelatin and maltodextrin might be tighten the three-dimensional network of emulsion due to ordered construction of molecules but in full-fat sample only egg yolk was used as an emulsifier agent. Mun *et al*. (2009) similarly reported that emulsion stability of manufactured full-fat and supplemented xanthan gum mayonnaise samples were more than 4αGTase-treated starch sample.

The result showed that full-fat mayonnaise had the highest brightness (L*). This can be explained that lower emulsion droplet size in the full-fat sample probably decreased scattering of light in comparison to low-fat samples (Chantrapornchai *et al*., 1999). However, the yellowness value of low-fat mayonnaise increased, as expected with increasing in fish gelatin due to increase of β-carotene content. Canthaxanthin or β-carotene can reduce color saturation and brightness. Krinsky and Johnson (2005) similarly reported that the yellowness of low-fat mayonnaise samples was higher than full in fat samples. Some investigators reported adverse effects of hydrocolloids when they play a role as a fat substitutes in the color of low-fat mayonnaise (Worrasinchai *et al*., 2006). However, the results were not in agreement with Su *et al*. (2010) reports that revealed when mayonnaise fat replaced with Xanthan gum, citrus fiber and guar gum the brightness value was improved compared to the full fat sample. Hence, Mun *et al*. (2009) reported that increasing in Xanthan gum and Starch in the emulsion formulation would increase L* value, that is not in agreement with our findings.

Increasing in hardness in low-fat samples containing fish gelatin could be possibly due to slow post-crystallization process and development of fat crystal networks which are resulted in condensed structure of T40 sample and consequently more force was desired to breaking down the structure (Alexa *et al*., 2011). A relationship between our results and Worrasinchai *et al*. (2006) report are notable. Therefore an increasing in hardness in low-fat products could be due to emulsion structure changed and maintain mono-dispersed condition instead of poly-dispersed state of O/W emulsions. Also, Liu *et al*. (2007) reported that the properties of low-fat mayonnaise reduced at level of 50% (cheese water, pectin, and methoxyl) are not noticeably influenced by aqueous phase. Depree and Savage (2001) and Gómez-Guillén *et al*. (2009) also found that the texture of O/W emulsions was significantly affected by viscosity of aqueous phase due to functional groups of hydrophilic and hydrophobic molecules of fish gelatin, especially cold water species gelatin, probably increasing in fish gelatin reduced emulsion oil index and keep it more endure. Fish gelatin may amend the spreadibility and reduce the free water to bound water normally due to the large amount of water incorporated (Williams *et al*., 2006). Therefore, sticky and viscous values of the low-fat samples were increased.

The texture features was correlated with the data derived from texture analyzer given. Total acceptance scores of T25 and T40 samples were higher than T0 (control) sample. This could be due to rougher differences in aroma, firmness or appearance parameters in the low fat samples compared to full-fat sample. Su *et al*. (2010) similarly reported that overall acceptability for reduced-fat mayonnaises that was markedly better could be due to changes in starch/gum ratio replacement, which turn consequence on gelling process of starch/gum mixed systems. According to Worrasinchai *et al*. (2006), the appearance score was significantly decreased in low-fat mayonnaises with more than 50% substitution of fat by β-glucan due to poor flavor release characteristics. Stern *et al*. (2001) also demonstrated the similar sensory characteristic of low-fat mayonnaise at 50% fat replacement with β-glucan. It can be concluded that the proper replacement level of fat by different hydrocolloids in mayonnaise is probably below 50% to maintain sensory properties, thereby in this study fish gelatin was substituted by fat up to 40% to create a smooth and creamy texture low-fat product. In this study the overall acceptability scores of a commercial mayonnaise (Tabarok Food Industry, Mashhad, Iran) evaluated with the same sensory panel were ranged from 3.50 to 4.80 (data not shown). Therefore, sensory scores higher than 3.50 are considered acceptable when compared with the T0 sample. Thus, T40 sample with replacement level of fish gelatin with oil up to 40% were judged to be sensorially accepted due to break down easily and give good flavor release in the mouth.

CONCLUSION

We should consider that fish gelatin can be gratefully used to produce low-fat as well as low-caloric mayonnaise. This finding also suggested that fish gelatin from bones of bighead carp is applicable to produce low-fat O/W emulsion food systems. However, in order to confirm the obtained data, it would be desirable to test rheological properties of the low-fat mayonnaise.

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