



Possibility of using 'chickpea aquafaba' as egg replacer in traditional cake formulation

Geleneksel kek formülasyonunda yumurta yerine nohut suyu kullanımı

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ABSTRACT

The objective of this study was to determinate the possibility of substituting egg with chickpea aquafaba at different levels (0-25-50-75-100%) in cake formulation and the quality characteristics of cake made with aquafaba. Physical (color analysis, volume index, symmetry index, and uniformity index), chemical (moisture, pH ash, protein) and sensorial properties of the cake samples were evaluated. 25% aquafaba-75% whole egg and 50% aquafaba-50% whole egg mixtures resulted in higher foaming capacity values than whole egg and the other replacement levels of aquafaba. Whole egg and aquafaba gave similar foaming stability values. While the use of up to 25 % aquafaba gave similar volume index values with control cake sample. Using more than 50% aquafaba in cake formulation concluded with an increase in firmness values. 50% aquafaba added cake sample showed desired uniformity index values close to 0.00 mm. Results showed that increasing the aquafaba in the cake samples from 0 to 100% decreased crumb redness. The results of sensory evaluation indicated that samples containing 25% aquafaba were more preferred by panelists.

Key Words: Aquafaba, Cake, Chickpea water, Egg, Egg replacer

ÖZ

Bu çalışmada, kek formülasyonunda yumurta yerine %0-25-50-75-100 oranlarında nohut suyu ikame edilebilme potansiyeli araştırılmış ve nohut suyu ile üretilen kek örneklerinin kalite karakteristikleri belirlenmiştir. Kek örneklerinin fiziksel (renk analizi, hacim indeksi, simetri indeksi, tek düzelik), kimyasal (rutubet, pH, kül, protein) ve duyu özellikleri incelenmiştir. %25 nohut suyu-%75 tüm yumurta ve %50 nohut suyu -%50 tüm yumurta karışımları, yumurta ve nohut suyunun diğer ikame oranlarına göre daha çok köpük kapasitesi değeri göstermiştir. %25 nohut suyu kullanımı ile kontrol örneğe benzer hacim indeksi değeri elde edilirken %50 den fazla nohut suyu kullanım oranı hacim indeksinde düşmeye ve kek sıklığında bir artışa sebep olmuştur. %50 nohut suyu kullanılan kek örneğinde 0.00 mm değerine yakın istenen tek düzelik indeks değeri elde edilmiştir. Kek içi kırmızılık değerinin %0 dan %100 e nohut suyu kullanımı ile azaldığı belirlenmiştir. Duyusal analiz sonuçlarına göre panelistler tarafından %25 nohut suyu içeren kek örneği daha çok tercih edilmiştir.

Anahtar Kelimeler: Aquafaba, Kek, Nohut suyu, Yumurta, Yumurta ikamesi

Introduction

Cake is a ready-to-use food product produced by using 8-9% protein wheat flour, sugar, fat, eggs, milk and some additives (Noğay, 2014; Köklü and Özer, 2008). Eggs are the most

important component in cake formulation in terms of both cake texture and nutrition. Egg white proteins are responsible for foam formation, emulsification, stabilization, elasticity while egg yolk used as binding, coloring, flavoring and emulsification agents (Lin et al. 2017a;

Kiosseoglou et al., 2014). Despite these positive effects, the consumption of eggs is limited for some individuals because of personal dietary preferences such as vegan-vegetarian, egg allergy, religious beliefs and health problems such as health diseases (Arozarena et al., 2001).

Aquafaba is the perfect solution for these diseases. Various studies have been carried out to develop alternative egg substitutes which can be used partially or completely instead of eggs in cake formulations as lentil protein (Jarpa-Parra et al., 2017), pea proteins (Lin et al., 2017b), soybean protein isolates (Lin et al., 2017a), soy milk (Rahmati and Tehrani, 2014a; Hedayati and Tehrani, 2018), whey proteins (Paraskevopoulou et al., 2015), hydrocolloids and emulsifiers (Shao et al., 2015; Rahmati and Tehrani, 2014b). Aquafaba is also known as 'sticky liquid da among the people. The reason for this is that when the legumes are cooked, the starch inside them is absorbed by water and eventually breaks down into amylose and amylopectin and also protein and sugar are absorbed by cooking water together. Moreover, recently, the viscous liquid 'aquafaba' produced from cooked legumes is considered an egg substitution in many foods due to nutritional and functional properties such as foaming, emulsifying, binding and thickening (Mustafa et al., 2018).

The objective of the present study was to determine physical, chemical and sensorial quality properties of cake produced using different levels of 'chickpea aquafaba' instead of eggs.

Materials and Methods

Materials

Chickpea seeds, wheat flour, sugar, shortening, whole egg, salt, baking powder, vanillin purchased from a local market in Konya, Turkey. The other ingredients used in the cake were xanthan gum (Vatan Gıda, Istanbul, Turkey) and diacetyl tartaric acid esters of monoglycerides and diglycerides (DATEM; Rikevita Sdn Bhd, Johor, Malaysia).

Aquafaba Production

Aquafaba was obtained by cooking chickpea with water (1:5 chickpea/water ratio) for 30 min in boiling water at 98 °C then waited for 12 hr and drained with modifying the procedure of Baik and Han (2012).

Methods

Control cake recipe from Rahmati and Tehrani (2014b) was used, with slight modifications. Cake prepared with wheat flour (100 g), shortening (50 g), sugar (75 g), egg (60 g), milk powder (8 g), salt (0.2 g), baking powder (3 g), vanillin (1 g), DATEM (0.5 g) and xanthan gum (0.5 g). Other cake samples were produced using 25-50-75-100 % ratio aquafaba instead of eggs. Control cake sample was prepared using 60 g egg without incorporation of aquafaba. The water amount in the recipe determined between 35 and 45 ml based on pre-trials. To obtain the cakes, sugar and egg were blended to a cream in a Hobart mixer (Hobart N50, Canada Inc., North York, Ontario, Canada) at a high speed for 5 min firstly. Later, other ingredients were added into the mixer and mixed for 1 min. For each cake, 130 g of cake batter was poured into a cake pan (7.5×6.6×12 cm) and baked at 160 °C for 50 min in a preheated oven (Bosch HBT 112, Athens, Greece). The cake samples were kept at room temperature to cool for 60 min before analyses.

Foaming capacity and foam stability of whole egg, aquafaba and mixtures thereof in different proportions were determined according to modification of Liu et al., 2010 and Martinez et al., 2016. 15 ml egg replacer in a 50 ml graduated cylinder were foamed using an digital ultra-turrax at 10000 rpm for 2 min, and then were measured foam volume at 0 min (V_{F0}) and after 30 min (V_{F30}). Foaming capacity and foam stability were calculated using Eqs.1 and 2, respectively,

$$\% \text{ Foaming Capacity} = \frac{VF_0}{V_{\text{samples}}} \times 100 \quad (1)$$

$$\% \text{ Foam Stability} = \frac{VF_{30}}{VF_0} \times 100 \quad (2)$$

The raw materials and the cake samples were analyzed for their moisture (AACC 44-01), ash (AACC 08-01), and protein (AACC 46-12) according to AACC (1990). The color of cake samples was determined measuring L^* (lightness/darkness), a^* (redness/greenness) and b^* (yellowness/blueness) parameters with a colorimeter (Model CR 400 Chromo meter, Minolta, Japan). Chroma and hue angle of cake samples were calculated from a^* and b^* . Cake batter pH was determined using a digital pH meter (WTW pH315i/set) by mixing 10 g dough with 90 ml distilled water for 1 min. Cake batter density was calculated by dividing the weight of a standard measure of the batter by the weight of an equal volume of water (Jyotsna et al., 2007). Volume, symmetry and uniformity index were calculated according to the AACC method 10-91 (AACC, 1990). Firmness was determined by a TA-XT2 Texture Analyzer (Texture Tech. Corp., England, and U.K.) at room temperature using an aluminium P36/R cylinder probe. The optimal test conditions in this study were: strain was 25%, and the pre-test, test and post-test speeds were 1.0, 1.0 and 10.0 mm/s, respectively.

The baking loss (%) was determined by dividing the difference between the weight of batter before and after baking and cooling to the weight of the batter before baking (Diaz-Ramirez et al., 2016). Sensory analysis of cake samples was conducted by 20 panelists (between 25 and 45 age) in the Food Engineering Department of Necmettin Erbakan University, Konya, Turkey. The panelists were selected based on their interest, non-smoker and non-food allergic. The sensory analysis was performed under daylight room

conditions, and samples were randomly presented. Sensory properties (color, smell, taste, pore structure, appearance and overall acceptability) of cake samples were rated on a 1–7 scale by panelists. Statistical analysis was performed by using JMP software.

Results and Discussion

Foaming properties of the egg which is one of the main ingredients of the cake production, contributes to improving structure/texture of batter and final products (Singh et al., 2016; Singh and Ramaswamy, 2013; Van der Plancken et al., 2005). Furthermore, the stability of the air bubbles formed in the protein network structure of the egg albumin during the foaming may be enhanced with the effect of the occurring film around the air bubbles as a result of protein denaturation which is the process of partial globular proteins (Liand and Kristinsson, 2007; Lomakina and Miková, 2006). The foam properties of the egg replacer used in the cake formulation are shown in Table 1. Foaming capacity values ranged from 126.67% to 253.33% and foam stability values ranged from 91.89% to 94.74%. Although aquafaba has a lower foaming capacity than egg, the use of aquafaba up to 50% level instead of egg was provided a statistically significant increase in foaming capacity. On the other hand, the foam stability of the aquafaba showed similar characteristics compared to the egg. There was no statistically significant difference between foaming stability values ($p>0.05$) in whole egg and aquafaba replacement levels.

Table 1. Foaming properties of egg and replacers¹

Çizelge 1. Yumurta ve ikamelerinin köpürme özellikleri¹

Samples <i>Örnekler</i>	Foaming capacity (%) <i>Köpük kapasitesi (%)</i>	Foam stability (%) <i>Köpük stabilitesi (%)</i>
100%Whole Egg	200.00±14.8 ^b	93.33±2.00 ^a
25%Aquafaba-75%Whole Egg	253.33±10.9 ^a	94.21±2.19 ^a
50%Aquafaba-50%Whole Egg	246.67 ± 8.9 ^a	91.89±2.04 ^a
75%Aquafaba-25%Whole Egg	186.67±12.7 ^c	92.14±1.40 ^a
100%Aquafaba	126.67±11.9 ^c	94.74±1.03 ^a

¹Means followed by the same letter within column are non-significantly different ($P < 0.05$).

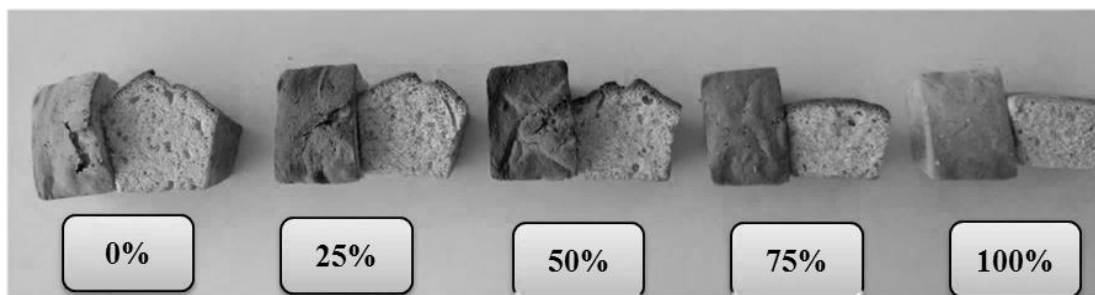


Figure 1. Cake samples

Şekil 1. Kek örnekleri

The prepared chickpea aquafaba was incorporated into traditional cake at 25, 50, 75 and 100%, as an egg substitute. Figure 1 presents the obtained cakes.

Chemical composition of cake samples are given in Table 2. As a result of cooking of legumes, water soluble carbohydrates such as sugar, sucrose, raffinose, stachyose and verbascose are dispersed into the cooking water (Stantiall et al., 2018; Ghribi et al., 2015). Therefore, dry matter of cake samples increased with the use of more than 50% chickpea aquafaba addition rate, compared to the control sample. The protein content of cake samples varied from 6.39 to 9.98% and decreased ($P<0.05$) with 100% chickpea aquafaba addition ratio but this decrease is just about 3%. Ash contents of cake samples varied from 1.20 to 1.30% and ash contents of cake samples decreased with

aquafaba addition. But 25% aquafaba added cake sample gave statistically similar ash content with control sample. This can be explained as follows, although high protein was found in chickpea seeds, less water soluble protein or ash pass into the cooking water seems to be the reason (Stantiall et al., 2018; Cherian et al., 2012). Batter density values are given in Table 2. The highest density was obtained from control cake batter incorporated with egg. Similar result was found by Jyotsna et al., (2007) a study used whey protein concentrate instead of egg.

Optimum cake volume, cake pore structure and texture are obtained by providing the appropriate pH value (Pylar, 1988). As shown in Table 2, the pH value of the cake sample decreased from 7.24 to 6.70, aquafaba addition resulted lower pH values compared to control sample.

Table 2. Chemical properties and batter gravity of cake samples.¹Çizelge 2. Kek örneklerinin kimyasal özellikleri ve hamur yoğunluğu¹

Aquafaba (%)	Dry matter (%)	Protein (%)	Ash (%)	Batter pH	Batter gravity (g cm ⁻³)
Nohut suyu (%)	Kuru madde (%)	Protein (%)	Kül (%)	Hamur pH	Hamur yoğunluğu (g cm ⁻³)
0	79.63±0.43 ^c	9.98±0.18 ^a	1.30±0.01 ^a	7.24±0.17 ^a	1.10±0.04 ^a
25	78.87±0.37 ^c	7.53±0.15 ^b	1.29±0.03 ^a	7.09±0.12 ^{ab}	1.08±0.01 ^{ab}
50	82.62±0.31 ^a	7.26±0.19 ^{bc}	1.25±0.03 ^{ab}	7.10±0.11 ^{ab}	1.03±0.02 ^{bc}
75	82.98±0.39 ^a	7.00±0.16 ^c	1.22±0.01 ^b	7.06±0.11 ^{ab}	1.04±0.03 ^{bc}
100	80.75±0.28 ^b	6.39±0.15 ^d	1.20±0.01 ^b	6.70±0.14 ^b	1.01±0.02 ^c

¹Means followed by the same letter within column are non-significantly different ($P<0.05$).

The increase in the cake batter pH is caused an increase in cake volume and large cake pore structure, while a decrease in cake batter pH is lead to firmer cakes, smaller pore structure, and lower cake volume (Pylar, 1988). As was expected, the volume index values of the cake samples decreased from 169 to 128 mm as a result of the pH change resulting from egg substitution (Table 3). According to

Paraskevopoulou et al. (2015), the decrease in cake volume is due to the better gas retention capacity of the control batter with higher ratio egg and a more controlled structure development during baking. Cake volume depends on not only air incorporated in the batter but also to retain available air during cooking (Paraskevopoulou et al., 2015; Sahi and Alava, 2003). A similar result was reported by Tan et al. (2015) that the egg-

free cake samples had a lower volume. Cake symmetry index values were ranged between 3 and 16 mm. In the cake industry, the symmetry index is used to determine the profiles of the outer lines of the cakes and the increase in the symmetry index indicates that the cake is formed from the center to the top and booming, and that the cake has a flat top surface (Mercan, 1998; Bath et al., 1992). Uniformity index values ranged from -0.45 to 0.25, also the highest value was determined with cake samples used 25% chickpea aquafaba. The uniformity index in the cake industry is used to determine the symmetry of the cake (Masoodi et al., 2002; Mercan, 1998). It is desirable that the results obtained are close to

zero (Mercan, 1998; Bath et al., 1992). 50% aquafaba added cake sample gave creditable (0.00 mm) uniformity index values.

Baking loss and firmness values of cake samples are demonstrated in Table 3. Results showed that as chickpea aquafaba ratio increased, the baking loss was changed from 12.72 to 13.74 but this change was not statistically significant ($P < 0.05$). The changes in baking loss values can be explained by the fact that the egg-containing cake formulations have a higher water binding capacity than the formulations prepared with egg substitution (Ratnayake et al., 2012).

Table 3. Physical properties of cake samples.¹

Çizelge 3. Kek örneklerinin fiziksel özellikleri¹

Aquafaba (%) Nohut suyu (%)	Volume index (mm) Hacim indeksi (mm)	Symmetry index (mm) Simetri indeksi (mm)	Uniformity index (mm) Tek düzelik İndeksi (mm)	Baking loss (%) Pişme kaybı (%)	Firmness (g) Sıklık (g)
0	169±2.12 ^a	15.5±0.14 ^{ab}	-0.45±0.07 ^c	12.72±1.78 ^a	508.26±29.5 ^c
25	165.5±2.12 ^a	8.5±0.28 ^{cd}	0.25±0.14 ^a	13.21±1.50 ^a	545.60±34.44 ^{bc}
50	158±1.41 ^b	16.0±0.21 ^a	0.00±0.07 ^{ab}	13.48±1.48 ^a	569.05±35.86 ^{bc}
75	130.5±2.12 ^c	3.0±0.14 ^d	-0.40±0.14 ^c	13.19±1.60 ^a	610.13±25.27 ^{ab}
100	128±2.12 ^c	10.0±0.28 ^{bc}	-0.20±0.07 ^{bc}	13.74±1.88 ^a	656.35±39.54 ^a

¹Means followed by the same letter within column are non-significantly different ($P < 0.05$).

Firmness values of cake samples produced with 100% chickpea aquafaba were significantly higher compare to the control cake samples ($P < 0.05$). An increase in firmness values was determined in cake samples contained isolated pea proteins instead of eggs by Lin et al. (2017b). Crumb and crust color of cake samples are presented in Table 4 and Table 5, respectively. Crumb lightness (L^*) of the cake samples varied between 69.71 and 73.00 with different chickpea aquafaba addition level. More than 75% addition level of aquafaba showed statistically similar lightness values with control cake sample. In

addition, crumb a^* values slightly increased at higher replacement levels of egg, and b^* values significantly decreased. Because the internal temperature of cake is not high enough for the formation of the Maillard and caramelization reactions, cake crumb color values are mostly dependent on the cake ingredients (Levent and Bilgiçli, 2013; Gómez et al., 2010). Egg, especially yolk is the main factor of changes the color of cake. Crumb chroma values of cake samples significantly ($P < 0.05$) decreased and also hue angle values decreased slightly.

Table 4. Crumb color properties of cake samples.¹

Çizelge 4. Kek örneklerinin kabuki renk özellikleri¹

Aquafaba (%) Nohut suyu (%)	L^* Parlaklık	a^* Kırmızılık	b^* Sarılık	Chroma	Hue angle
0	73.00±1.02 ^a	-0.42±0.03 ^c	24.91±0.19 ^a	24.92±0.19 ^a	90.97±0.03 ^a
25	69.71±0.85 ^b	-0.41±0.04 ^c	23.91±0.22 ^b	23.91±0.22 ^b	90.98±0.04 ^a
50	71.93±1.12 ^{ab}	-0.38±0.03 ^c	22.59±0.26 ^c	22.60±0.26 ^c	90.97±0.08 ^a
75	72.57±0.99 ^a	-0.26±0.03 ^b	20.56±0.22 ^d	20.56±0.22 ^d	90.73±0.24 ^{ab}
100	72.99±1.08 ^a	-0.13±0.01 ^a	19.41±0.20 ^e	19.41±0.20 ^e	90.37±0.02 ^b

¹Means followed by the same letter within column are non-significantly different ($P < 0.05$).

Compare to control samples, using 100% chickpea aquafaba increased the crust lightness of cake samples significantly ($P<0.05$), whereas crust redness values of cake samples significantly decreased ($P<0.05$). Results of the crust color represented that yellowness value of control cake higher than the other cake samples with chickpea aquafaba. Both chroma and hue angle values of cake crust color significantly decreased until 75% chickpea aquafaba addition compare to control cake samples. Crust color of cake is affected

Maillard reactions, interaction reducing sugars-amino acids and caramelization reactions of sugars (Hedayati and Tehrani, 2018). According to Rahmati and Tehrani (2014a), the reason for this increase may be due to the higher protein content of the egg than egg substitutions.

Sensory properties of cake samples are shown in Figure 2. Generally, control sample (without chickpea aquafaba) is given the highest score in terms of all

Table 5. Crust color properties of cake samples.¹

Çizelge 5. Kek örneklerinin iç renk özellikleri¹

Aquafaba (%) Nohut suyu (%)	L^* Parlaklık	a^* Kırmızılık	b^* Sarılık	Chroma	Hue angle
0	49.21±1.48 ^b	12.07±0.24 ^a	28.30±0.34 ^a	30.77±0.41 ^a	66.90±0.16 ^a
25	50.42±1.52 ^{ab}	11.63±0.25 ^{ab}	25.30±0.26 ^b	27.84±0.34 ^b	65.31±0.25 ^b
50	50.59±1.54 ^{ab}	11.01±0.25 ^{bc}	21.68±0.25 ^c	24.32±0.34 ^c	63.08±0.26 ^c
75	52.40±1.45 ^{ab}	11.14±0.22 ^{bc}	18.39±0.33 ^d	21.50±0.39 ^d	58.81±0.05 ^d
100	53.51±1.54 ^a	10.86±0.27 ^c	25.31±0.28 ^b	27.55±0.36 ^b	66.78±0.30 ^a

¹Means followed by the same letter within column are non-significantly different ($P < 0.05$).

sensory characteristics. Compared to the control samples, the use of aquafaba up to 75% level in cake samples showed statistically similar color scores and the lowest color scores was given for 100% aquafaba added cake samples by the panelists. The most affected property was the smell among the sensorial properties. Smell scores decreased with aquafaba addition. According to the taste scores of the cake samples, the use of egg substitution until 50% level was shown similar effect with control cake, but with 75 and 100% substitution of aquafaba instead of

egg, the samples received lower scores from panelists. Pore structure scores decreased with aquafaba addition because of the shrinkage of the pores and a tighter structure in the cake. In terms of appearance, the use of aquafaba up to 25% level in cake samples showed statistically similar color scores compared to control cake. According to overall acceptability properties, similar features of control cakes with up to 50% usage were observed and no negative effects were observed.

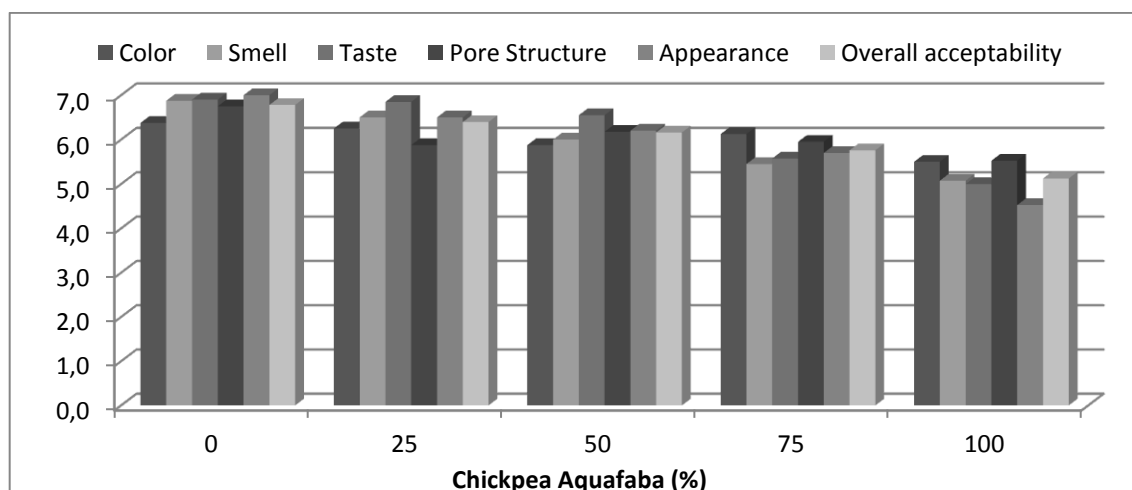


Figure 2. Sensory properties of cake sample

Şekil 2. Kek örneklerinin duyusal özellikleri

Conclusions

When all the results are evaluated, the use of chickpea aquafaba as an egg substitute was concluded with a decrease in the protein and ash content of cake samples, and in terms of physical properties considerably not caused a negative effect up to 50% ratio and showed similar foaming stability values. Addition of egg substitution resulted in an increase of crumb redness and a decrease of crust yellowness values. Compared to the control samples, the use of aquafaba up to 75% level in cake samples showed statistically similar color scores. As a result, chickpea aquafaba can be used 50% as an alternative source instead of eggs for vegans with regard to both cost and effects on nutrition.

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