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Assessment The Effects of Psyllium And Hydrocolloids in Gluten-Free Noodle

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HIGHLIGHTS

- Psyllium utilization was evaluated accompanied with two different gums.
- Combination of psyllium with other two gums resulted in higher cooking quality.
- Textural analysis showed consistency with cooking quality results.

Abstract

This study was performed to examine the effects of individual and combined usage of psyllium husk powder (PHP) with guar gum (GG) or locust bean gum (LBG) on the production of gluten-free Turkish-type noodles. For this purpose, six different formulations were created with the total amount of variables being 3%, and samples' physical, chemical, cooking, textural and sensorial properties were performed. The results revealed no significant decrease or increase in moisture, ash, protein and fat contents. On the other hand, although individual usage of psyllium caused a slight decrease in carbohydrate content, this did not reflect energy values. The lowest *L** and hue and the highest *a** values were observed in the samples where only psyllium was used, and there was no significant difference in *b** and saturation index values. Regarding cooking quality and textural analysis, the results from these two analyses supported each other, and there is a significant difference between the samples. An additional disliking that can be considered significant was not determined by using psyllium with or without other gums in noodle formulation. As a result, the dual combined psyllium with other gums in gluten-free noodle production could be appropriate without adversely affecting the quality of the product.

Keywords: gluten-free; guar gum; locust bean gum; noodle; psyllium husk.

1. Introduction

Coeliac disease (CD) is a well-known food intolerance affecting approximately 1% of the world population (Lionetti et al. 2015). This disease, also known as gluten enteropathy, is triggered by consuming wheat, rye and barley protein (Foschia et al. 2016; Dahal et al. 2021). After consuming these cereals by genetically susceptible individuals, small intestinal damage emerges, which causes digestion problems and

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malabsorption of nutrients (Allen and Orfila 2018; Kastin and Buchman 2002). Since it is a lifelong intolerance, CD patients should avoid gluten and products that include gluten (Yalcin and Basman 2008a). Therefore, gluten-free or modified cereal products were developed targeting these patients.

Turkish noodle, locally called 'erişte', is a traditional cereal-based food including egg, wheat flour and salt (Ozkaya et al. 2004). In recent years, the fortification of erişte was investigated by enrichment with different food components such as dairy by-products, apple fibre and chia flour (Aktaş and Türker 2015; Yuksel and Gurbuz 2019; Levent 2017) to increase the health benefits and functionality. Some of these fortification studies focused on people with gluten sensitivity or CD; thus, noodle formulation was modified with different gluten-free cereals (corn, rice), pseudocereals and legumes (Bilgicli 2008; Bilgicli 2013; Yalcin and Basman 2008a). However, replacing gluten with other ingredients is crucial for gluten-free products since gluten provides the structure, rheological and organoleptic features in dough systems. Mainly, hydrocolloids such as hydroxypropyl methylcellulose (HPMC), carrageenan, xanthan gum, locust bean gum (LBG) and guar gum (GG) can be used for this purpose (Allen and Orfila 2018; Belorio et al. 2020). Owing to their water-holding, gelling and thickening properties, they can help to form intermolecular networks; thus, they improve the structure and quality of the products (Dahal et al. 2021). In gluten-free pasta and noodle formulations, hydrocolloids affect the dough properties, and they change the colour, firmness and hardness of the pasta by increasing the firmness of the protein-starch matrix. Therefore, the cooking quality, mouthfeel, overall acceptability and dough kneading in noodles may also be enhanced (Culetu et al. 2021). Furthermore, these gums are also known as 'dietary fibre'; thus, adding these gums into gluten-free cereal formulas improves the nutritional quality of products while potentially reducing the glycaemic index of the foods (Brennan and Tudorica 2007). However, increasing interest in dietary fibre emerged in the inquiry of new fibre sources to enhance its capability and utilisation in the food industry. Thus, new food design can be accomplished, and the textural and sensory quality of products can be improved while increasing the fibre intake (Noguerol et al. 2022).

Psyllium is a soluble polysaccharide and natural fibre obtained from the seed of *Plantago ovato* (Belorio et al. 2020). It mainly consists of arabinose, xylose and other sugars such as galactose, rhamnose, glucose, and mannose (Zhang et al. 2019). It is also highly branched in the xylan backbone, which leads to high water-binding capacity and high viscosity in food systems. Therefore, it can be used as a thickening agent, emulsifier and stabiliser in food applications (Beikzadeh et al. 2016). Moreover, this viscous polysaccharide can form gels, enabling its usage in processed foods while lowering the glycaemic index of the food thanks to its dietary fibre content (Fradinho et al. 2020). The usage of psyllium in cereal and gluten-free bakery products has previously been suggested and investigated. In these researches, its effect has been investigated as a gluten substitute (Zandonadi et al. 2009), as a hydrocolloid substitute (Ziemichód et al. 2019), as a fat replacer (Belorio et al. 2019) and as combined with other gums (Mancebo et al. 2015) in food formulas. As it is used as a hydrocolloid, psyllium also improves the bread structure, volume and texture while reducing the glycaemic index in gluten-free bread. Furthermore, psyllium is a fibre source in bakery products, increasing the dietary fibre content of noodles (Culetu et al. 2021).

This study investigated the influence of a hydrocolloid of psyllium husk (PHP) in Turkish gluten-free noodle production and its effect on the end product's physicochemical, sensory and cooking quality. In this study, the two most used hydrocolloids, LBG and GG, were also used to compare the effect of psyllium in noodle formulation. Furthermore, these two gums are also paired with psyllium to characterise the physicochemical, textural and sensory qualities of the Turkish gluten-free noodle.

2. Materials and Methods

2.1. Materials

For gluten-free noodle production, commercial rice flour, corn starch, whole egg and salt were purchased from local markets from Karaman, Türkiye. Psyllium husk powder were obtained from Doğavera Gıda Co. (İstanbul, Türkiye). Guar gum and locust been gum were purchased from Sigma-Aldrich (USA).

2.2. Noodle preparation

Noodle samples were produced by adjusting the method of Levent (2017). Noodles was prepared with 100 g gluten-free flour mix (50% rice starch, 50% corn starch), 0.5% salt, 30% egg. The hydrocolloids; guar gum, locust bean gum and psyllium husk were added into the formulations according to Table 1. The amount of water was variable. The ingredients given in Table 1 were blended and mixed with a laboratory type mixer (Kitchen Aid Artisan Series Mixer; Kitchen Aid, St. Joseph, MI, USA) for 5 min. Before processing the noodle dough as sheets (2mm thick), it was divided into three pieces and rested at room temperature for 15 min in polyethylene bags. After that, the sheets were cut as 6mm wide long stripes with using a noodle machine (Vitalia Pasta Machine, İzmir, Turkey). Following the cutting process (4.5 cm long pieces) of these long stripes, the noodle samples were dried at ambient conditions till the moisture content of end product no more than 10%.

Table 1. Formulations of gluten-free noodle samples (g)

Samples	Gluten-free flour mix	Whole egg	Salt	PHP	GG	LBG
S1	100	30	0.5	3	-	-
S2	100	30	0.5	-	3	-
S3	100	30	0.5	-	-	3
S4	100	30	0.5	1.5	1.5	-
S5	100	30	0.5	1.5	-	1.5
S6	100	30	0.5	1	1	1

2.3. Chemical analysis

Noodle samples were analysed for their moisture (method 44-19), ash (method 08-01), fat (method 30-25) and protein (method 46-12) contents (AACC, 1990). The moisture content was determined using the drying norm at 135 °C. For the determination of ash content, the samples were burned at 550 °C. Protein determination was made by the Kjeldahl method and a multiplication factor of 6.25 was used in the calculation. For fat determination, the samples were extracted with hexane using a soxhelet device and then the solvent was removed.

2.4. Colour Analysis

The colour of noodle samples was measured using Hunter Lab Chroma Meter (Minolta CR-400, Osaka, Japan) in terms of the Hunter *L** (white; black), *a** (red; green) and *b** (yellow; blue) values. Besides, saturation index (SI) – Chroma, and Hue angle values were calculated according to equations below:

$$SI: (a^{*2} + b^{*2})^{1/2}) \quad (1)$$

$$Hue: \text{Arctan } [b^{*} a^{*-1}]) + 180 \text{ where } a<0 \text{ and } b>0 \quad (2)$$

$$Hue: \text{Arctan } [b^{*} a^{*}-1] \text{ where } a>0 \text{ and } b>0 \quad (3)$$

For colour measurement, the samples were grounded with a blender (Sinbo SCM-2934; Sinbo, Istanbul, Turkey), sieved from 500 µm opening screen and the samples' colour were measured with the granulated material in a glass container. The measurements were done as triplicate and the average value of these readings were given.

2.5. Cooking Quality of Noodle Samples

For determination of cooking quality of samples, weight increase (WI), volume increase (VI) and cooking loss (CL) were monitored according to method of Özkaya and Kahveci (2005). 10 g noodle sample was boiled for 18 minutes in 250 ml distilled water and drained. Weight and volume of the samples were specified and recorded before cooking and after draining. A precision scales and a graduated cylinder filled with distilled water were used for determination of WI and VI respectively. The weight difference and water overflow in cylinder were used for calculation WI (%) and VI (%) respectively. On the other hand, for CL, the cooking water was evaporated to constant weight and total solids were expressed as percentage.

2.6. Texture Analysis

The firmness values of cooked gluten-free noodle samples were measured using a texture analyser model TAXT Plus Texture Analyser (Stable Micro Systems, Surrey, UK). The samples were sheared with A/LKB-F probe and the measurements were performed with load cell of 5 kg. The tests were carried out in duplicate and the average values were stated. Results were given as g (AACC 2000).

2.7. Sensory analysis

For sensorial evaluation, 100g of noodle samples were cooked in 500 ml boiling distilled water with 2.5 g salt up to optimum cooking time and drained in a colander. A laboratory panel was installed in an area far from the work area under daylight room conditions. The noodle samples with randomized order on a plate were presented to 7 panellists. They evaluated the samples regarding colour, cohesiveness, chewiness, taste, odour and overall acceptability by using a 7-point hedonic scale (1 = dislike extremely, 4 = acceptable and 7 = like extremely).

2.8. Statistical analyses

The results were displayed as mean ± standard deviation. SPSS statistics software (SPSS Inc., Chicago, IL, USA) was used for statistical analyses. The differences obtained from results was assessed by One Way Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test at 5% confidence interval.

3. Results

3.1. Chemical Analysis

The results of fat, protein, moisture, ash and carbohydrate are given in Table 2. According to this table, the differences between the samples were insignificant. However, different hydrocolloids showed a slight effect on the moisture of the glute-free noodles. Thus, the moisture content of sample S2 had the lowest moisture content and this data was consistent with Sutheeves et al. (2020).

Table 2. Proximate composition of noodle samples

	Moisture (g)	Ash (g)	Protein (g)	Fat (g)	Carbohydrate (g)	Energy (g)
S1	9.45±0.21^{a}	0.80±0.09^{a}	7.38±0.21^{a}	3.64±0.12^{a}	78.75±0.21^{b}	377.20±1.08^{a}
S2	9.11±0.06^{a}	0.78±0.01^{a}	7.12±0.23^{a}	3.30±0.08^{a}	79.71±0.10^{ab}	376.96±0.16^{a}
S3	9.27±0.21^{a}	0.78±0.06^{a}	7.08±0.04^{a}	3.36±0.08^{a}	79.52±0.40^{ab}	376.64±0.65^{a}
S4	9.44±0.10^{a}	0.69±0.07^{a}	7.06±0.18^{a}	3.76±0.32^{a}	79.06±0.33^{ab}	378.26±2.27^{a}
S5	9.14±0.25^{a}	0.82±0.08^{a}	6.81±0.08^{a}	3.72±0.17^{a}	79.52±0.08^{ab}	378.78±1.56^{a}
S6	9.34±0.26^{a}	0.79±0.04^{a}	6.71±0.19^{a}	3.32±0.28^{a}	79.86±0.38^{a}	376.10±0.19^{a}

* Means followed by different letters in the same column are significantly different ($p<0.05$).

On the other hand, samples S1 and S4 were higher than others, indicating the effect of PHP's high water-holding capacity. A similar effect was observed by Pejcz et al. (2018) when psyllium was added to the gluten-free bread formula. The ash contents of the samples were found to be almost at the same values since the addition of the gums was very low; there were not any significant differences among the samples. Considering protein, S1 had the highest protein ratio among all the samples. This situation showed that adding only PHP into the formula as a hydrocolloid resulted in the highest protein amount since PHP includes approximately 2.5% of protein (Aldughpassi et al. 2021). Therefore, adding 3% of PHP resulted in a slight increment in protein ratio, which also agreed with other research (Fradinho et al. 2020). On the other hand, although individual usage of psyllium (S1) caused a slight decrease in carbohydrate content, this did not reflect in energy values.

3.2. Colour analysis

The colour parameters (L^*, a^*, b^*, and colour intensity) of the uncooked noodle samples are presented in Table 3. As it can be seen, the colour of the gums slightly affected the colour and brightness of the noodle samples. All the samples had higher L^* values, which might increase the tendency of consumers to consumption of them since bright colours of noodles are generally desirable by consumers (Srikaeo et al. 2018). However, when the samples were examined individually, S1 (%3 PHP) was recorded with the lowest value of L^* colour (less lightness), which was significantly different from the other samples. On the other hand, redness (a^*) was also increased for the same sample while lightness decreased. The same observation was noted with Peressini et al. (2020) and Renoldi et al. (2021), where a^* increased with the increment of PHP ratio in the pasta formula. Ziemichód et al. (2019) expressed that PHP addition to the gluten-free bread as a hydrocolloid darkened the crumb colour owing to its phenolic component. In terms of yellowness, there was no significant differences between the samples. The addition of locust bean gum increased the yellowness of noodles, and Yalcin and Basman (2008b) also obtained similar results when transglutaminase and locust bean gum were used together in noodle formulations.

Table 3. Colour measurements of noodle samples

Samples	L^*	a^*	b^*	**Chroma**	***Hue***
S1	91.08±0.14^{b}	2.12±0.03^{a}	11.96±0.28^{a}	12.15±0.29^{a}	79.99±0.11^{d}
S2	91.65±0.07^{a}	1.89±0.01^{bc}	11.88±0.04^{a}	12.03±0.05^{a}	81.00±0.03^{b}
S3	91.85±0.27^{a}	1.83±0.05^{c}	12.20±0.39^{a}	12.33±0.40^{a}	81.48±0.05^{a}
S4	91.71±0.08^{a}	1.93±0.01^{bc}	11.53±0.00^{a}	11.70±0.01^{a}	80.51±0.03^{c}
S5	91.97±0.04^{a}	1.93±0.04^{bc}	11.61±0.12^{a}	11.77±0.13^{a}	80.57±0.07^{c}
S6	91.80±0.01^{a}	2.00±0.03^{ab}	11.93±0.05^{a}	12.09±0.06^{a}	80.52±0.09^{c}

* Means followed by different letters in the same column are significantly different ($p<0.05$).

3.3. Cooking Quality of Noodle Samples

The cooking quality of noodles is an essential parameter for consumer acceptance and industry, which is generally assessed by measurement of weight increase (WI), volume increase(VI) and cooking loss (CL). Since low CL and high volume and weight increase are preferred and evaluated as high cooking quality, these features are examined for the noodle and pasta samples (Zhou et al. 2013). According to Table 4, all noodle samples had a significant effect ($p < 0.05$) on WI, VI, and CL of all the samples. WI and VI values of all noodles were found to be 88.24- 113.56% and 105.00- 141.22%, respectively. Among the samples, S3 showed the highest volume, weight increase, and lower cooking loss after cooking. Tan and her co-workers also examined the similar effect of LBG when they added 1.5% LGB into salt-free noodles (Tan et al. 2018). This lowest cooking loss effect of LBG was associated with gum's ability to help gel formation of the noodle network; thus, noodles were stable during the cooking process (Han et al. 2011).

On the other hand, the lowest WI, VI and highest CL were found for S6, which was a combination of all three hydrocolloids. These results showed that %1 addition of each hydrocolloid might not be applicable for gluten-free noodle production, although individual usage of each hydrocolloid had better values than combinations. Since noodles' preferred cooking loss is at most 12%, S6 might not be evaluated as good quality noodles (Ugarcic-Hardi et al. 2007). Moreover, this CL value of S6 might indicate the lower structural strength of noodles and this was correlated with firmness results (refer to Fig 1.) (Sutheeves et al. 2020). On the other hand, the CL value of S1 was the second highest value, which shows that PHP might not be an alternative for LBG or GG. Although its swelling capability and thickening ability was stated higher in dough systems, it did not present the WI and VI values in noodle as high as with LBG and GG. However, WI and VI values of S5, which was higher than S1, pointed out that combining PHP with LBG enhanced the cooking quality of noodles.

Table 4. Cooking properties of gluten-free noodles

	Weight Increase WI (%)	**Volume Increase VI (%)**	**Cooking Loss CL(%)**
S1	93.98±0.82^{bc}	111.25±1.77^{bc}	11.63±0.66^{ab}
S2	97.87±0.60^{bc}	123.75±1.77^{abc}	8.51±0.36^{bc}
S3	113.56±5.97^{a}	141.22±7.69^{a}	7.64±0.70^{c}
S4	104.92±1.34^{b}	105.83±0.60^{c}	9.79±0.76^{bc}
S5	112.80±1.44^{a}	131.25±8.84^{ab}	8.23±0.01^{c}
S6	88.24±3.44^{c}	105.00±7.07^{c}	14.56±1.44^{a}

* Means followed by different letters in the same column are significantly different ($p<0.05$).

3.4. Texture Analysis

In addition to less cooking loss and high cooking yield values, the cooking quality of noodles is generally assessed with high firmness (Marti et al. 2013). As presented in Figure 1, the firmness of noodles was significantly ($p < 0.05$) affected by hydrocolloid type and features used for the formula. The amount and type of hydrocolloids influence starch gelatinisation and protein-starch network in noodles; thus, the structure of noodles and the release of solid components in cooking water are varied (Gasparre and Rossel 2019). Furthermore, it can be noted that the firmness results were compatible with cooking quality results, where the highest score was obtained for the sample containing 3% LBG (S3). However, adding PHP in gluten-free noodle formulation lowered the firmness results, which Fradinho and her co-workers previously observed while examining the effect of PHP in gelatinised and non-gelatinised noodle production (Fradinho et al. 2020). A combination of GG and PHP (S2) in the noodle showed higher firmness than PHP alone (S1). Kaur et al. (2015) examined higher firmness values for GG than xanthan gum when these gums were added to corn noodles. However, in this study, LBG addition presented better values than GG.

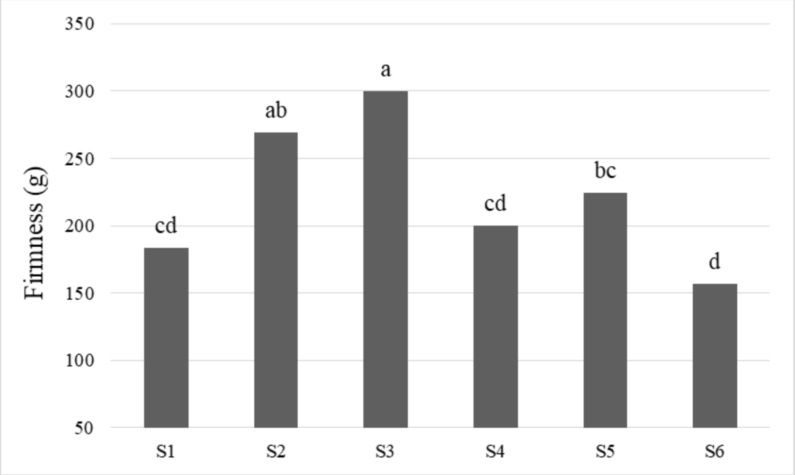

Figure 1. Firmness of noodle samples

On the contrary, the triple combination of LBG, GG and PHP decreased the firmness of sample S6, which has already been observed in cooking quality results. Therefore, this analysis confirmed that the combination of these three hydrocolloids did not synergistically impact of noodle quality. However, instead of applying LBG and PHP together in gluten-free noodle production might be more suitable than just PHP addition as a hydrocolloid in the formula. Thus, this implementation may increase the dietary fibre and amino acid quality by lowering the glycaemic index of the gluten-free noodles. On the other hand, Renoldi et al. (2021) obtained higher firmness values of spaghetti when the PHP ratio in the formula was increased. It is noteworthy that the cooking quality might improve if the PHP addition rate increases in the noodle formula.

3.5. Sensory analysis

The sensory analysis was applied to all formulations with different combinations of the hydrocolloids and PHP regarding colour, cohesiveness, chewiness, taste, odour and overall acceptability. As shown in Figure 2, samples were scored close to each other and the sensory analysis was insignificantly affected by different formulations. There was not a significant difference in all sensory criteria. The colour, cohesiveness, chewiness, taste, odour and overall acceptability scores ranged between 6.6-6.9, 4.5-5.3, 5.9-6.6, 5.5-6.5, 5.8-6.3, 5.5-6.3 respectively. These values were expected since hydrocolloids and PHP do not have a distinct colour, odour and taste. Beikzadeh et al. (2016) that the overall acceptability values were between 3.68 - 4.76 when the PHP level reached a 15% maximum. Furthermore, in that study, it was stated reported that there were no differences between PHP added and control cake regarding all sensory attributes.

On the other hand, Zandonadi et al. (2009) pointed out that PHP addition to gluten-free bread did not change the consumer choice for accepting the new product. Moreover, they found that this gluten-free bread with PHP was not preferred by CD patients when it was compared with the commercial gluten-free products.

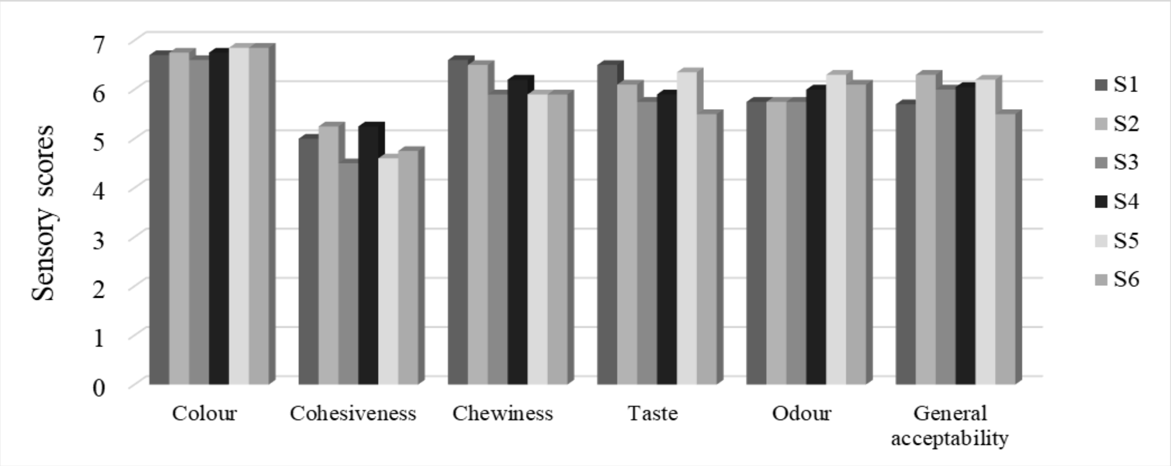

Figure 2. Sensory evaluation of noodle samples

4. Conclusions

This study revealed the effects of PHP utilisation combined with or without GG and LBG on some properties of Turkish gluten-free noodle samples. The results showed significant changes in cooking and textural properties rather than chemical, physical and sensory properties. Data obtained from the cooking quality and textural analyses had consistency and suggested that either a combination of LBG–PHP or GG-PHP might be used in the formulations. As a result, it was seen that the combination of PHP and LBG or GG in gluten-free noodle production could be appropriate without adversely affecting the quality of the product. We hope our findings about PHP offer an alternative to industrial gums such as guar gum and locust bean gum. Future studies can be carried out to investigate the usage of PHP in different forms and ratios in order to increase the usage rate of PHP in Turkish-type noodle samples. In addition, its application with other gums other than guar and locust bean gums in gluten-free noodle production may be investigated accompanied by advanced techniques.

Author Contributions: The authors have an equal contribution. All authors have read and agreed to the published version of the manuscript.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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