Nutritional, functional and sensory evaluation of flaxseed-enriched cupcakes

Sarah Ali Farooq[1], Samra Imran[2*], Afifa Tanweer[3]

[1]College of Home Economics and Management Sciences, Islamabad, Pakistan.
[2]Queen Mary Graduate College, Lahore, Pakistan.
[3]Department of Nutrition & Dietetics, School of Health Sciences, University of Management and Technology, Lahore, Pakistan.

*Corresponding author: Samra Imran (Email: samra.imran74@gmail.com)

ABSTRACT

Purpose: Snacking is quite a common preference in this busy world. Increasing the availability of healthier snack alternatives might help consumers view snacks as foods that support health.

Design/Methodology/Approach: The current experimental study aimed to determine the nutritional, functional and sensory properties of home-baked cupcakes encouraged with six variants with indigenous flaxseed flour (FF) and flaxseed oil (FO) in 10, 15 and 30% of batter substitution. A one-way ANOVA, least significant difference and Pearson's correlation were applied using IBM SPSS version 21.0.

Findings: Proximate analysis indicated an increase in ash, fiber and protein contents as compared to the standard formulation. The highest ash (1.91±0.26%), fiber (1.09±0.01%) and protein contents (3.08±0.30%) were observed in the sample FF30 (30% flaxseed flour). The cupcakes with 30% flaxseed oil had a significantly greater fat content (35.91±0.55%) and hence a total calorie value of 221.00±3.17%. Antioxidant activity and phenol content of fortified cupcakes ranged from 32.88–76.02% and 22–80 mgGAE/100 gms respectively. The sensory evaluation proved FF15 and FO30 to be the most acceptable recipes.

Conclusion: Minor recipe alterations to snacks may yield large and long-term health benefits especially promoting immunity and reducing the risk of inflammatory chronic illnesses. Flaxseed oil might be used in snacks substituting for other vegetable oils to enhance the essential fatty acid content without compromising its acceptability. New formulations could therefore be tested to develop foods fortified with higher proportions of functional and nutritious ingredients especially given the ever-increasing prevalence of chronic illnesses.

Keywords: *Antioxidants, Cupcake, Functional foods, Immune function, Snacking, Nutrient profile, Organoleptic properties.*

1. INTRODUCTION

Children prefer starchy foods such as instant noodles, stewed rice, cake and snacks. Strategies have been developed to include functional ingredients in more frequently consumed food items to encourage the consumption of healthier foods (Xu et al., 2017).

Flaxseeds are a source of high-quality proteins, fibers, lignans, omega-3 and omega-6 rich oil and other biologically active components that have been shown in the following studies to support the use of flaxseeds in the prevention of certain non-communicable diseases. The fatty acid combination as found in flaxseeds has been linked to brain development, visual and reproductive health (Roby, 2017) management of Parkinson's disease (Taghizadeh et al., 2017) cardiovascular disease (CVD), metabolic syndrome, diabetes mellitus (Drenjančević et al., 2017) and hypercholesterolemia (Edel, Aliani, & Pierce, 2015). Moreover, flaxseeds are a practical alternative for people with low access to marine food because they provide them with a good source of omega-3 fatty acids. The addition of flaxseed flour to baked products is beneficial for increasing the consumption of fiber and omega-3 fatty acids in the diet. New formulations could therefore be evaluated to develop foods fortified with higher proportions of

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functional and nutritious ingredients (Moraes et al., 2010). The food quality of baked items may also be retained through the addition of flax seeds. The antioxidant qualities of lignan in flaxseeds maintain the lipid content of the seed throughout processing and heating. Various researchers have stressed the beneficial aspects of enriching common foods with functional food ingredients (Xu et al., 2017). The consumer acceptability test revealed that bread with 30% and 45% flaxseed flour had 5.6% and 7.2% of alpha-linolenic acid (De Lamo & Gómez, 2018). Flaxseed-enriched muffins were associated with better glycemic response and insulin resistance in a randomized cross-over design study (Almehmadi, Lightowler, Clegg, & Chohan, 2018). Therefore, previous research suggests that adding functional food components to common foods might have positive health effects (Xu et al., 2017). A study on the nutritive value, phenolic content and antioxidant analysis of home-baked cupcakes may therefore provide encouragement to add functional foods to home cooking.

The present study aims to determine the nutritional composition, antioxidant capacity, total phenol content and sensory analysis of home-baked cupcakes fortified with indigenous flaxseed flour and flaxseed oil. It may help in promoting healthy snacking among youth and encourage entrepreneurs to introduce functional ingredients to conventional baked products for health-conscious customers.

2. METHODS

The research study was carried out to compare the nutritional, antioxidant and phenolic content of home-baked cupcakes cooked with different recipes and also evaluate their organoleptic properties.

2.1. Preparation of Cupcakes

The recipe for a standard cupcake included flour (1 cup -180 g), sugar (½ cup – 125 g), oil (¼ cup – 65 g), milk (½ cup - 125 g), baking powder (1 tsp - 5 g), baking soda (½ tsp - 2.5 g), egg (2 – 100 g) and water (1/3 cup - 47.5 g). Its preparation was done in the following steps:

1. The oven was preheated to 350°F.
2. Only the bottom of the cupcake pan was greased and cupcake papers were inserted to fit the bottom of the cupcake pan.
3. Flour, baking soda and baking powder were sifted together.
4. Eggs and oil were mixed followed by the addition of powdered sugar and then mixed again.
5. After mixing for a minute, half the flour mixture and half the milk were added alternately. Subsequently, the remaining flour and liquid were added and mixed for 30 seconds at a medium speed followed by a further 3 minutes at a high speed.
6. The batter was poured into the designated spot on the cupcake pan. Each cupcake weighing approximately 50 g (raw weight) and is baked at 350°F for approximately 25 minutes.
7. Cupcakes were cooled for 5 minutes before being removed from the pan.

The standard recipe was adapted from the instructions for a shortened cake described by Peckham and Freeland-Graves (1979). The weight of each cupcake was kept at 50 grams (the raw weight of the batter). Six variations of the standard recipe were made through fortification by manipulating two variables: i. Flaxseed oil (FO) ii. Flaxseed flour (FF). The ingredients (indigenous brown flaxseeds (*Linum Usitatissimum*) and locally packaged flaxseed oil) for modified recipes were procured from the local market in Lahore, Pakistan. Recipes were varied according to the following proportions: FO10% (45-gram standard batter+5g FO), FO15% (42.5 g standard batter + 7.5 g FO), FO30% (35g standard batter+ 15g FO), FF10% (45-gram standard batter+5g FF), FF15% (42.5 g standard batter + 7.5 g FF) and FF30% (35g standard batter+ 15g FF).

All six modified recipes along with the standard recipe were subjected to further experiments. All the experimental work was performed in the food and Biotechnology Research Centre (FBRC) of the Pakistan Council of Scientific and Industrial Research (PCSIR) laboratories complex, Lahore.

2.2. Proximate Analysis of Cupcakes

The moisture, ash, protein, fat, fiber and total carbohydrate content of each item were determined using the official techniques of analysis established by the Association of Official Analytical Chemists (2012).

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2.3. Determination of Antioxidant Activity and Total Phenolic Content

Determination of Antioxidant Activity: A slightly modified method of DPPH bleaching assay was used to determine the antioxidant activity of extracts. Extracts and the DPPH mixture were placed in a glass cuvette and the absorbance changed at 517nm for 30 seconds using a UV-VIS spectrophotometer equipped with a multi-cell holder. The percentage of DPPH consumption was calculated in each case. The higher the rate of DPPH consumption, the more powerful the antioxidant capacity.

$$\text{Percentage of DPPH inhibition} = \frac{\text{Blank reading} - \text{sample reading}}{\text{Blank reading}} \times 100$$

Blank reading = Absorbance of the control reaction mixture excluding the sample which is DPPH.

Sample reading = Absorbance of the sample.

Determination of total phenolic content: The total phenolic content of the extract was determined using the modified Folin-Ciocaltu method. 0.2 mL of the extract (1 mg/ml) was mixed with 0.2 ml of Folin-Ciocaltu reagent (1:10 v/v distilled water) and 1 ml (75 g/L) of sodium carbonate. The absorbance was read at 765 nm with a spectrophotometer.

The recipes developed were subject to organoleptic evaluation by ten semi-trained panelists who were selected through convenience sampling techniques. The panelists were informed about study objectives, protocols and oral consent. Each panelist was asked to have an empty stomach for at least two hours before opting for sensory evaluation. The room was arranged with white light and comfortable sitting. Each individual was provided with approximately 10 gm of each sample coded as S, FF10, FF15, FF30, FO10, FO15 and FO30 on white disposable plates. They were directed to rinse their mouths after tasting each sample. The samples were subjected to the affective acceptance test with a 5-point hedonic scale as 1= extremely bad, 2= bad, 3= good, 4= very good and 5= extremely good. The sensory analysis evaluated attributes of appearance, taste, texture, aroma and overall acceptability. A structured questionnaire was adapted for sensory evaluation from previous research with slight modifications (Gomes, Sanches, Dos Santos, Manhani, & Novello, 2014).

Acceptability Index (AI): The index calculation for the acceptability of seven formulations was performed using the formula: AI (%) = 100 x A / B (where A = average score obtained for the product and B = maximum score given to the product).

2.4. Statistical Analysis

The results of all experiments were expressed as the mean ± standard error of the mean. A one-way ANOVA, least significant difference and Pearson's correlation were applied using IBM SPSS version 21.0.0. All statistical testing was done at 95% CI with $p<0.05$ considered significant.

2.5. Proximate Analysis of Cupcakes

The proximate nutrient analysis of cupcakes is summarized in Table 1. Results of a one-way ANOVA indicated that the inclusion of flaxseed flour significantly ($p<0.05$) increased the ash, fiber and protein content of cupcakes while moisture was significantly ($p<0.05$) decreased with the increase of flaxseed flour and oil. The highest ash (1.91±0.26%), fiber (1.09±0.01%) and protein contents (3.08±0.30%) were observed in the sample FF30 (30% flaxseed flour). Fat content (35.91±0.55%) and thus total kcal/cupcake (221.00±3.17%) were considerably greater in 30% flaxseed oil cupcakes. However, a difference in the fatty acid profile is expected.

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Table 1. Proximate analysis of standard cupcakes and cupcakes fortified with flaxseed flour and flaxseed oil per 100 g (n=7).

Nutrient profile	Standard	FF10	FF15	FF30	FO10	FO15	FO30	F	P
Moisture (%)	16.78±1.41	15.41±0.83	12.33±0.65	10.32±0.27	11.49±1.93	12.96±2.08	12.16±1.92	7.20	<0.001
Ash (%)	1.02±0.10	1.24±0.22	1.56±0.09	1.91±0.26	0.99±0.02	0.94±0.05	0.95±0.11	20.16	<0.001
Fat (%)	19.86±0.71	21.31±0.17	22.50±0.34	29.18±0.54	28.22±0.12	29.21±0.83	35.91±0.55	346.18	<0.001
Fiber (%)	0.66±0.05	0.90±0.04	1.01±0.02	1.09±0.01	0.16±0.02	0.15±0.01	0.10±0.03	681.47	<0.001
Protein (%)	2.16±0.12	2.11±0.07	3.02±0.54	3.08±0.30	2.23±0.21	2.10±0.13	1.80±0.08	10.91	<0.001
Carbohydrates (%)	60.19±0.69	59.95±0.72	61.08±0.41	55.35±1.12	57.07±2.05	54.32±3.15	48.94±2.85	15.56	<0.001
% of Kcal from carbohydrates (Kcal/Cupcake)	100.78±0.83	100.75±1.27	102.60±0.70	92.99±1.87	95.88±3.44	91.25±5.30	82.23±4.79	15.49	<0.001
% of Kcal from Protein (Kcal/Cupcake)	3.63±0.20	3.54±0.12	5.07±0.91	5.18±0.50	3.75±0.35	3.5±0.22	3.02±0.14	10.84	<0.001
% of Kcal from fats (Kcal/Cupcake)	75.06±2.68	80.56±0.66	85.06±1.27	110.30±2.05	106.67±0.45	110.41±3.14	135.75±2.09	346.72	<0.001
Total Kcal(Kcal/Cupcake)	179.46±3.57	184.86±1.55	192.74±0.69	208.47±0.25	206.30±3.08	205.20±4.70	221.00±3.17	78.31	<0.001

Note: Flaxseed oil (FO), Flaxseed flour (FF); FO10% (45-gram standard batter+5g FO), FO15% (42.5 g standard batter + 7.5 g FO), FO30% (35g standard batter+ 15g FO), FF10% (45-gram standard batter+5g FF), FF15% (42.5 g standard batter + 7.5 g FF) and FF30% (35g standard batter+ 15g FF)

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Table 2 illustrates the results of the least significant difference (LSD) test which was conducted to see the pair-wise comparison between cupcakes regarding their moisture, ash and fiber content. There was a significant difference (p<0.05) in the moisture content of the standard cupcake and all others except FF10. All six formulations were significantly different in fiber content. The amount of ash varied greatly between FF15 and FF30. However, it is revealed that with a higher percentage of flaxseed flour, there is a decrease in moisture content and an increase in ash and fiber content. There was no noticeable rise in the amount of moisture, ash and fiber in cupcakes baked with flaxseed oil.

Table 2. Pairwise comparison of standard cupcake about moisture, ash and fiber content of flaxseed fortified recipes (n=7).

Recipes	Moisture		Ash			Fiber	
	Mean difference (I-J)	Std. error	Mean difference (I-J)	Std. error	Sig.	Mean difference (I-J)	Std. error
FF10	1.37	1.19	-0.22	0.12	0.078	-0.25*	0.02
FF15	4.45*	1.19	-0.54*	0.12	<0.001	-0.35*	0.02
FF30	6.46*	1.19	-0.89*	0.12	<0.001	-0.43*	0.02
FO10	5.29*	1.19	0.02	0.12	0.845	0.50*	0.02
FO15	3.82*	1.19	0.07	0.12	0.542	0.51*	0.02
FO30	4.62*	1.19	0.07	0.12	0.579	0.56*	0.02

Note: *statistically significant (<0.01).

Table 3 depicts the results of the LSD test which was conducted to see the pair-wise comparison between cupcakes regarding their carbohydrate, protein and fat content. There was a significant difference (p<0.05) in the carbohydrate content of standard cupcakes with FF30, FO15 and FO30 having a lower carbohydrate content than standard. Protein content significantly increased with an increase in flaxseed flour. Thus, FF15 and FF30 were found to have more protein content than the standard. Flaxseed oil formulations revealed no significant increase in protein content. There was a significant difference (p<0.05) in the fat content of the standard cupcake compared to all others.

Table 3. Pairwise comparison of standard cupcake for carbohydrates, protein and fat content of flaxseed fortified recipes (n=7).

Recipes	Carbohydrates		Protein			Fat	
	Mean difference (I-J)	Std. error	Mean difference (I-J)	Std. error	Sig.	Mean difference (I-J)	Std. error
FF10	0.23	1.53	0.05	0.21	0.804	-1.46*!	0.43
FF15	-0.89	1.53	-0.86*	0.21	<0.001	-2.65**	0.43
FF30	4.83*	1.53	-0.92*	0.21	<0.001	-9.32**	0.43
FO10	3.11	1.53	-0.07	0.21	0.733	-8.36**	0.43
FO15	5.87*	1.53	0.06	0.21	0.792	-9.35**	0.43
FO30	11.24*	1.53	0.36	0.21	0.107	-16.06**	0.43

Note: *Statistically significant p<0.01; *! Statistically significant p<0.05; **Statistically significant p=0.000.

2.6. Effect of Cupcakes Formulations with Flax Seed on the Acceptability Index

In terms of general acceptability, both standard and FO30 scored equally despite FO30's lower ratings for appearance and scent. Among flaxseed formulations, FF15 was the most accepted and among flaxseed oil formulations FF30 was the most accepted (see Table 4).

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Table 4. Acceptability index scores and organoleptic properties of cupcakes (n=7).

Samples	Appearance% N=7	Taste%	Texture%	Aroma%	Over acceptability%	Total%
Standard	74	62	56	66	72	66
FF10	52	48	48	48	42	48
FF15	56	60	54	56	60	57
FF30	50	48	60	52	50	52
FO10	64	58	56	48	58	57
FO15	62	54	38	56	52	52
FO30	70	64	62	58	76	66

2.7. Total Phenol Content and Antioxidant Activity

The total phenol content and antioxidant activity of all seven formulations of cupcakes have been shown in Table 5. FF30 had the highest total phenolic content and antioxidant activity (80 and 76.02) respectively.

Table 5. Phenolic content and antioxidant activity of seven formulations of cupcakes.

Samples	Total phenolic content	Antioxidant activity
Standard	14	21.86
FF10	53	66.15
FF15	60	70.6
FF30	80	76.02
FO10	25	42.26
FO15	24	36.36
FO30	22	32.88

A significant ($p<0.05$) positive relationship between total phenol concentration and antioxidant activity was found indicating an increase in antioxidant properties with an increase in phenolic content (see Table 6).

Table 6. Relationship between total phenol concentration and antioxidant activity of various recipes of cupcakes.

Characteristic	Phenol concentration (µg/g GAE) (r)	Number of samples
Antioxidant activity	0.969*	7

Note: *Statistically significant $p<0.001$.

3. DISCUSSION

Flaxseeds have become an invaluable functional food ingredient due to their high lignan, ALA and fiber content. Recent studies have confirmed the benefits of using flaxseeds as a functional food ingredient in baked goods, drinks, milk and dairy products, muffins, macaroni and meat products (Goyal, Sharma, Upadhyay, Gill, & Sihag, 2014; Zou et al., 2017).

The nutritional composition of the standard cupcake and all six formulations indicated a significant ($p<0.05$) difference regarding energy, moisture, carbohydrate, protein, fat, fiber and ash content. Cupcakes made with flaxseed flour had considerably higher protein, fibre and ash contents ($p<0.05$). Fat content was considerably greater in flaxseed oil cupcakes (see Table 1). So, it can be deduced from the current study that adding flaxseed flour to bakery products can be a useful strategy to promote the consumption of fiber and omega-3 in the diet. The findings of the current study were in line with the results of a similar study by Wandersleben et al. (2018) who discovered that wheat bread enriched with flaxseed flour had higher levels of protein, fiber, ash and essential fatty acids.

Cupcakes fortified with 15% flaxseed flour provided 200% of the recommended dietary allowance (RDA;1.2 – 2.2 g/day) of alpha-linoleic acid while those fortified with 15% flaxseed oil was revealed to provide 150% of the RDA of ALA along with a compromise on ash, protein and fiber content which was significantly high in flaxseed flour formulations. A higher percentage of flaxseed flour and oil incorporation resulted in decreased carbohydrate content and an increase in fat content which was consistent with the findings of another study Mervat, Mahmoud,

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Bareh, and Albadawy (2015) which also revealed that diets containing flaxseed increased the level of serum high-density lipoprotein (HDL-C), while serum total cholesterol (TC), triglyceride (TG), low-density lipoprotein (LDL-C) and very-low-density lipoprotein (VLDL-C)significantly decreased due to the presence of essential fatty acids and antioxidants.

A significant ($p<0.05$) relationship between total phenol concentration and antioxidant activity has been found. The findings indicated a related increase in antioxidant activity with the elevated phenol level (see Table 5). These outcomes were consistent with the findings of Russo and Reggiani (2015) who demonstrated the relationship between antioxidant activity and total phenolic content and found that foods with higher phenolic content were associated with higher levels of antioxidant activity. The same study also found less antioxidant activity in flaxseed oil products as compared to flaxseed flour products, thus presenting flaxseed flour as a better functional food to be consumed for greater health benefits. The main advantages of natural antioxidants present in omega-3 fatty acids are acceptability and preference at the consumer's end while no safety tests for natural antioxidants are required by legislation, so home-based use can be encouraged. The phenolic compounds in flaxseeds have been positively linked with the nutritional and sensory qualities of foods (Roby, 2017).

The scope of further research on the nutritional composition of cakes during home handling such as home-baked products was suggested by Mercier et al. (2014). The current study on home-baked cupcakes revealed similar benefits as commercially manufactured flaxseed flour fortified products. Flaxseed in one of its various forms has to be incorporated into food products called functional foods or sprinkled onto foods before consumption to promote adherence to its regular consumption for its possible cardio protective role (Edel et al., 2015). The functional properties demonstrated in flaxseeds have been found to improve the immune function of the body in addition to treating chronic diseases (Biao et al., 2020). Adequate eating is being encouraged to boost the body's immunological systems in the wake of the current epidemic (Yousfi, Bragazzi, Briki, Zmijewski, & Chamari, 2020). Therefore, adding flaxseeds to homemade snacks might be useful for promoting general health and immune function.

Among flaxseed formulations, FF15 (57%) and FO30 (66%) were the most accepted (see Table 4). Our results are in accordance with a similar study on carrot cupcakes fortified with flaxseed flour, the formulation with 18% flaxseed flour was the most accepted one (Gomes et al., 2014). The 10 and 15% flaxseed flour fortification in wheat bread was found to be the most accepted when compared to the one with a 20% addition (Kaur et al., 2018). Bakker and Courtial (2017) found a 10% substitution of wheat flour with flaxseed flour in pasta to be acceptable. Thus, similar incorporations of flaxseed flour in cupcakes as well as in other food products may enhance the nutritional composition of commonly used foods.

The novelty of this study lies in the fact that for the first-time flaxseed flour is incorporated into cupcakes. It will not only make it easier for a homemaker to prepare the recipe easily at home but also provide a substantial quantity of flaxseed flour in one cupcake without compromising much on acceptability. The most accepted and nutritious formulation among the flaxseed flour is FF15 which has been shown to have higher protein (3.02%), ash (1.56%), fiber (1.01%) than the standard cupcake (protein 2.16%, ash 1.01% and fiber 0.66%) (see Table 4). The most accepted formulation among cupcakes fortified with flaxseed oil was FO30 which scored better than the standard in taste, texture and overall acceptability. It was found to be highest in calorie content (221 Kcal), though with a better fatty acid profile but with less antioxidant activity (32.88%), phenol content (22 mg GAE/g), ash (0.95%), fiber (0.10%) and protein (1.80%) as compared to FF30 (208.47 Kcal, antioxidant activity 76.02%, phenol content 80 mg GAE/g, ash 1.91%, fiber 1.09% and protein 3.08%). Flaxseed flour has the benefit of providing lignin an excellent source of phenolic compounds, fiber and minerals that are lacking in flaxseed oil. The product development proved that a single serving of each of the six formulations is an excellent source of ALA. Cupcakes fortified with flaxseed flour provide the added benefits of lignan, fiber and protein. Flaxseeds are a rich source of various nutrients, antioxidants, total polyphenols and essential fatty acids that can help fight against many diseases and malnutrition problems emerging in developing countries like Pakistan.

Further studies on product development with substituting vegetable oil with flaxseed oil and the incorporation of synthetic or natural antioxidants to prevent lipid oxidation are highly warranted.

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4. CONCLUSION

The results suggest that flaxseed flour is a functional ingredient in food products and dietary supplement production due to its higher bioactive values as compared to flaxseed oil. Flaxseed oil might be used in snacks substituting for other vegetable oils to enhance the essential fatty acid content without compromising its acceptability. New formulations could therefore be tested to develop foods fortified with higher proportions of functional and nutritious ingredients especially in the current scenario for boosting immune function as well as decreasing chronic disease risk.

FUNDING

This study received no specific financial support.

INSTITUTIONAL REVIEW BOARD STATEMENT

The Ethical Committee of the Federal Government College of Home Economics and Management Sciences, Islamabad, Pakistan has granted approval for this study.

TRANSPARENCY

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

Conceived the research idea and conducted the experiments, S.A.F.; critically reviewed the research report, S.I.; assisted in manuscript preparation and organizing the research outcomes, A.T. All authors have read and agreed to the published version of the manuscript.

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