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The environmental impact of exposure to barbecue smoke on biochemical and hematological parameters of BBQ workers

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ABSTRACT

BBQ pitmasters are exposed daily to various gaseous and particulate pollutants during grilling or barbecuing traditional foods in many countries, including Iraq. These toxic emissions may have long-term effects on human health. In this study, biochemical, biophysical, and hematological investigations were performed to assess the effects of grilling emissions on BBQ workers, also known as BBQ pitmasters, in Hit City, Iraq. The results showed significant changes in several clinical biochemical and hematological biomarkers. For example, total protein, albumin, triglycerides, and very-low-density lipoprotein (VLDL) levels showed significant increases at $p < 0.05$. However, serum uric acid showed a significant decrease compared with the healthy control group. Collectively, the results suggest that exposure to grilling emissions may alter hematological values in the blood and may have potentially harmful effects on pitmasters. The study showed that five biochemical parameters out of 15 measured parameters and four hematological parameters out of 10 measured parameters showed significant changes in BBQ workers compared with healthy controls, possibly due to unsafe work practices followed during grilling.

Keywords: *BBQ pitmasters, Cardiac function, Grilling emissions, Polycyclic aromatic Hydrocarbons compounds PAHs, Kidney and Liver function*

1 INTRODUCTION

BBQ pitmasters are exposed daily to various gaseous and particulate pollutants during grilling or barbecuing foods, and exposure patterns may differ from one country to another [1]. In Iraq, wood and charcoal are commonly used for grilling food. Their fumes are produced through thermal oxidative decomposition and contain various hazardous chemical and physical pollutants, such as particulate matter (PM) and polycyclic aromatic hydrocarbons (PAHs) [2].

PAHs are a group of organic compounds consisting of two or more aromatic rings. They can also be found in fossil fuels, coal tar, creosote, and various other sources [3–6]. PAHs are of concern because they are known to have carcinogenic and mutagenic effects. Therefore, they are considered important environmental pollutants because they can persist in the environment for long periods and accumulate in the tissues of living organisms [7]. Several studies, especially those conducted in China, have reported their negative effects on aquatic life, wildlife, and human health [8–10].

These hazardous substances can directly affect the respiratory system, which may, in turn, influence blood components and related hematological parameters [11]. Therefore, studying these parameters may provide useful information for protecting pitmasters from different chronic or complicated diseases that may appear later in life. These effects may contribute to various unclear health conditions, including gastrointestinal and liver disorders, because of their influence on inflammatory and immune-related blood cells [12, 13].

In this study, we aimed to investigate the impact of grilling smoke on pitmasters who traditionally use wood and charcoal for grilling. Routine biochemical and hematological parameters were examined in approximately 40 pitmasters and compared with the same number of healthy individuals living in the same district.

2 MATERIALS AND METHODS

All biochemical kits used with the fully automated Automatic Biochemistry Analyzer SPIN200E, including GOT, GPT, uric acid, urea, creatinine, and other assays, were compatible with the instrument. The compatible kits were supplied by Biosystems (Spain), Linear Chemicals, and Spinreact (Spain).

The study was conducted over 3 months at Hit General Hospital, Iraq. It included 84 participants: 42 healthy individuals serving as the control group and 42 middle-aged BBQ pitmasters aged 18–45 years who had worked in this occupation for 5 years or more. Blood samples from healthy controls were collected in the main laboratory of Hit General Hospital, whereas blood samples from pitmasters were collected at their workplaces.

The study included hematological, biochemical, and biophysical assessments. Complete blood count (CBC) examinations were performed immediately after blood collection, within less than 2 h [12, 13]. Serum samples were obtained after centrifugation at 3000 rpm for 15 min at 4 °C. The serum samples were stored at -80 °C until further analysis.

The study followed strict inclusion criteria. Only BBQ pitmasters and healthy controls without chronic diseases, such as diabetes mellitus and hypertension, were included to reduce the influence of other conditions that could affect the study results. One of the most important criteria was that all BBQ pitmasters had worked in this occupation for at least 5 years. Work duration was considered because biomarker measurements may vary according to exposure duration. Therefore, only pitmasters with $\geq$ 5 years of occupational experience exposure were included. In addition, only young and middle-aged participants were included. No major differences were observed between males and females within the study range; therefore, their results were not analyzed separately. The same criteria were applied to the healthy control group, except that controls had no occupational exposure as pitmasters.

2.1 Biochemical, biophysical and hematological assessment

Serum samples for biochemical assessment were analyzed using a fully automated biochemistry analyzer (Automatic Biochemistry Analyzer SPIN200E). Several groups of biochemical parameters related to kidney function, liver function, cardiac function, and lipid profile were assessed in this study. Specific gravity was assessed manually using a clinical refractometer specific gravity test device, model RP299.000. Routine hematological parameters were assessed using a CBC analyzer, Auto Hematology Analyzer MSLAB42 (Guangdong, China), in the same laboratories.

All data were collected and statistically analyzed using GraphPad Prism version 8.0. A t-test, descriptive analysis, one-way ANOVA, and paired-sample Wilcoxon test were used to detect significant differences in biomarkers compared with healthy controls. A p value <0.05 was considered statistically significant.

GraphPad Prism version 8.0.1 was used for statistical analysis. A t-test was performed to identify significant differences between the mean values of BBQ pitmasters and healthy controls. Only biomarkers showing significant differences are presented in the figures, whereas non-significant parameters are shown only in Tables.

3 RESULTS AND DISCUSSION

In this study, the effects of grilling emissions from traditional barbecued food prepared using wood and charcoal on BBQ workers, or pitmasters, were investigated in Hit City, Iraq. The study included 42 pitmasters who had worked in this occupation for 5 years or more and a similar number of healthy individuals as controls. All study results are indicated in Tables 1 and 2, and Figures 1 and 2.

The results showed that five biochemical parameters out of 15 measured parameters and four hematological parameters out of 10 measured parameters showed significant changes in BBQ workers compared with healthy controls. These changes may be related to unsafe occupational practices followed during grilling. For example, the biochemical biomarkers total serum protein, albumin, triglycerides, and very-low-density lipoprotein (VLDL) were significantly elevated in BBQ pitmasters. In contrast, serum uric acid was the only biochemical marker that showed a significant decrease compared with healthy controls.

Table 1 Descriptive statistics of the measured biochemical and hematological parameters in the control and BBQ-worker groups

Parameter	Group	*n*	Min.	Max.	Range	Mean	SD	SEM	CV
WBC	**Control**	40	4.21	14.28	10.07	7.463	2.133	0.3658	28.58%
	BBQ workers	40	3.83	13.06	9.23	8.394	1.947	0.329	23.19%
Neutrophil	**Control**	40	1.88	9.99	8.11	4.391	1.878	0.317	42.78%
	BBQ workers	40	2.05	8.41	6.36	4.669	1.386	0.2343	29.69%
Lymphocyte	**Control**	40	0.3	4.03	3.73	2.332	0.773	0.122	33.17%
	BBQ workers	40	1.25	4.03	2.78	2.766	0.7381	0.1167	26.68%
Monocyte	**Control**	40	0.1	1.8	1.7	0.5453	0.29	0.045	53.19%
	BBQ workers	40	0.18	62	61.82	2.22	9.697	1.533	436.9%
HGB	**Control**	40	8.2	17.3	9.1	12.46	1.896	0.299	15.22%
	BBQ workers	40	4.14	16.4	12.26	14.14	2.009	0.3176	14.21%
RBC	**Control**	40	3.24	6.09	2.85	4.744	0.6565	0.1038	13.84%
	BBQ workers	40	4.64	8.38	3.74	5.402	0.6099	0.09643	11.29%
HCT	**Control**	40	26.8	57.1	30.3	40.01	5.931	0.937	14.82%
	BBQ workers	40	23.7	52.1	28.4	44.66	4.858	0.768	10.88%
MCV	**Control**	40	58.8	95	36.2	83.82	7.402	1.17	88.31
	BBQ workers	40	66.2	92.5	26.3	84.95	5.06	0.8	59.57
MCH	**Control**	40	19.7	29.9	10.2	26.48	2.217	0.350	83.7
	BBQ workers	40	19.1	30.6	11.5	27.09	2.056	0.3251	75.91
HCHC	**Control**	40	28	33.1	5.1	31.13	1.081	0.170	34.71
	BBQ workers	40	28.8	33.8	5	31.86	1.075	0.17	33.75
GOT	**Control**	40	14	59	45	26.03	10.13	1.602	38.94%
	BBQ workers	40	16	82	66	29.75	11.19	1.77	37.62%
GPT	**Control**	40	9	102	93	31.38	19.9	3.146	63.42%
	BBQ workers	40	17	86	69	37.85	15.25	2.411	40.29%
ALP	**Control**	40	86	1096	1010	218.7	162.4	25.68	74.27%
	BBQ workers	40	113	954	841	222.3	132.3	20.92	59.53%
Protein	**Control**	40	3.4	8.24	4.84	6.376	1.023	0.161	16.04%
	BBQ workers	40	6.51	8.42	1.91	7.146	0.4344	0.06868	60.78
Albumin	**Control**	40	2.4	8.1	5.7	4.402	0.9603	0.1518	21.82%
	BBQ workers	40	4.6	5.6	1	5.073	0.1783	0.02819	35.15
Glucose	**Control**	40	66	472	406	120	78.54	12.42	65.43%
	BBQ workers	40	62	193	131	100.3	26.06	4.121	25.98%
Urea	**Control**	40	12	86	74	29.38	13.35	2.112	45.46%
	BBQ workers	40	20	51	31	30.63	6.674	1.055	21.79%
Creatinine	**Control**	40	0.1	12.9	12.8	1.253	1.907	0.301	152.3%
	BBQ workers	40	0.7	1.6	0.9	1.125	0.175	0.02768	15.56%
Uric acid	**Control**	40	4.2	8.6	4.4	6.033	1.099	0.173	18.22%
	BBQ workers	40	3.5	7.5	4	5.038	0.9032	0.1428	17.93%
Ca^{2+}	**Control**	40	6.8	13.6	6.8	9.365	1.314	0.207	14.03%
	BBQ workers	40	8.5	10.1	1.6	9.248	0.3644	0.05762	39.41
TG	**Control**	40	30	402	372	125.6	88.76	14.03	70.69%
	BBQ workers	40	64	921	857	227.1	172.7	27.31	76.04%
VLDL	**Control**	40	4.5	60	55.5	25.01	12.77	2.019	51.06%
	BBQ workers	40	13	184	171	45.5	34.49	5.454	75.81%
Cholesterol	**Control**	40	88	265	177	149.5	43.7	6.909	29.24%

Continued on next page

Table 1 (continued)

Parameter	Group	*n*	Min.	Max.	Range	Mean	SD	SEM	CV
	BBQ workers	40	1.52	271	269.5	167	45.53	7.199	27.27%
BMI	**Control**	40	54.05	63.29	9.237	60.05	1.794	0.283	29.88
	BBQ workers	40	18.43	85	66.57	30.58	12.18	1.926	39.83%
CRP	**Control**	40	1.06	19.98	18.92	5.189	2.907	0.459	56.03%
	BBQ workers	40	0	24.17	24.17	3.687	5.01	0.7921	135.9%
Specific gravity	**Control**	40	1.04	1.352	0.312	1.07	0.0809	0.0128	75.65
	BBQ workers	40	1.04	1.352	0.312	1.086	0.1015	0.01604	93.42

Note. SD, standard deviation; SEM, standard error of the mean; CV, coefficient of variation. Decimal punctuation was standardized; reported values were otherwise preserved.

Table 2 A statistical table shows the results of the unpaired ANOVA experiment analysis of measured biochemical and hematological parameters of both groups (Control & pitmasters workers). P-value was considered < 0.0001 for significant values*.

Parameter	p value	Summary	Significant at p < 0.05	Tail	t statistic and df
WBC	0.0623	ns	No	Two-tailed	t = 1.896. df = 67
Neutrophil	0.4831	ns	No	Two-tailed	t = 0.7053. df = 68
Lymphocyte	0.0122	*	Yes	Two-tailed	t = 2.567. df = 78
Monocyte	0.2784	ns	No	Two-tailed	t = 1.092. df = 78
HGB	0.0002	***	Yes	Two-tailed	t = 3.843. df = 78
RBC	<0.0001	****	Yes	Two-tailed	t = 4.649. df = 78
HCT	0.0003	***	Yes	Two-tailed	t = 3.836. df = 78
MCV	0.4299	ns	No	Two-tailed	t = 0.7935. df = 78
MCH	0.2113	ns	No	Two-tailed	t = 1.260. df = 78
HCHC	0.0036	**	Yes	Two-tailed	t = 2.998. df = 78
GOT	0.1227	ns	No	Two-tailed	t = 1.560. df = 78
GPT	0.1064	ns	No	Two-tailed	t = 1.633. df = 78
ALP	0.9119	ns	No	Two-tailed	t = 0.1109. df = 78
Protein	<0.0001	****	Yes	Two-tailed	t = 4.383. df = 78
Albumin	<0.0001	****	Yes	Two-tailed	t = 4.342. df = 78
Glucose	0.136	ns	No	Two-tailed	t = 1.506. df = 78
Urea	0.5979	ns	No	Two-tailed	t = 0.5295. df = 78
Creatinine	0.6749	ns	No	Two-tailed	t = 0.4210. df = 78
Uric acid	<0.0001	****	Yes	Two-tailed	t = 4.423. df = 78
Ca	0.5874	ns	No	Two-tailed	t = 0.5449. df = 78
TG	0.0014	**	Yes	Two-tailed	t = 3.307. df = 78
VLDL	0.0007	***	Yes	Two-tailed	t = 3.524. df = 78
Cholesterol	0.0829	ns	No	Two-tailed	t = 1.757. df = 78
BMI	<0.0001	****	Yes	Two-tailed	t = 15.14. df = 78
CRP	0.1052	ns	No	Two-tailed	t = 1.639. df = 78
Specific Gravity	0.448	ns	No	Two-tailed	t = 0.7625. df = 78

Specific Gravity 0.448 ns No Two-tailed t = 0.7625. df = 78

These findings may be interpreted in several ways. First, changes in hematological parameters among BBQ pitmasters may be related to altered lung function, which can induce inflammation and activate defense mechanisms [14–16]. A previous study showed that smoke exposure can increase blood leukocytes, neutrophils, lymphocytes, monocytes, hematocrit, hemoglobin, and mean corpuscular volume. It also reported associations between smoke exposure, white blood cell parameters, and red blood cell indices. In the present study, several biomarkers showed non-significant changes in pitmasters compared with healthy controls [17].

A similar study was previously conducted on individuals exposed to smoke from grilled fish. The findings showed that the exposed group had higher mean values of several hematological parameters than the control group, except for lymphocyte count and some other parameters. These changes were attributed to harmful compounds present in grilled fish smoke.

In the present study, the hematological biomarkers that were significantly increased in BBQ pitmasters included lymphocytes, hematocrit, red blood cell count, and hemoglobin [18–21]. Exposure to wood and grilling smoke may increase hematological biomarkers because of harmful pollutants present in the smoke. Such exposure may increase carbon monoxide levels in the blood, resulting in binding of carbon monoxide to hemoglobin and reducing its oxygen-carrying capacity. Consequently, tissue oxygenation may decrease, triggering a compensatory response by increasing red blood cell and hemoglobin production to improve oxygen delivery to tissues.

In addition, inhalation of grilling smoke may increase exposure to toxic substances and chemicals, such as particulate matter, polycyclic aromatic hydrocarbons (PAHs), and other pollutants. These substances may cause oxidative stress and inflammation, potentially damaging red blood cells and other blood components. Some of these chemicals have also been linked to an increased risk of hematological malignancies, such as leukemia. The significant increase in hemoglobin observed in this study may therefore reflect increased red blood cell production as a compensatory response [22–24].

Second, blood biochemical parameters may change because of respiratory exposure to fumes produced by burning wood, charcoal, and meat. These fumes may release several oxidative products, particulate matter (PM), metals, and PAHs. These products may directly affect blood components and induce inflammation and acid–base disturbances through changes in pCO_2, bicarbonate concentration, and metabolic acid–base balance, including alkalosis and acidosis [25–27].

Protein and albumin disturbances may be influenced by chronic inflammation or inflammatory disorders caused by fume inhalation, as suggested by previous studies. Oxidative stress and inflammation resulting from inhalation of these pollutants may damage hepatocytes, which are responsible for producing albumin. These pollutants may also stimulate cytokine production, which can reduce albumin synthesis by the liver and increase albumin breakdown in the blood. However, exposure to these fumes may also cause lung tissue injury, increasing permeability of the lung barrier and promoting the release of proteins, including albumin, from lung tissue into the bloodstream [28].

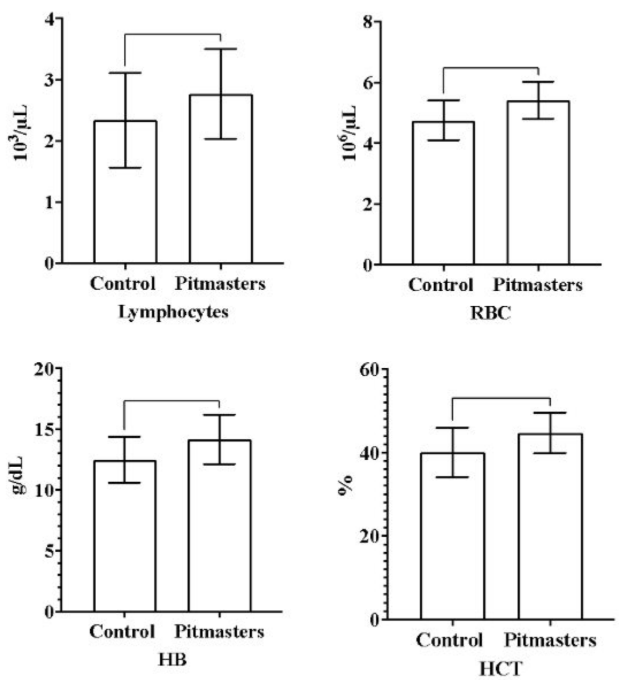

Fig. 1 shows the multiple sub-figures, labeled on bottom of them, for each hematological parameters examined for pitmasters compared to the healthy control. Figures show levels or percentage in specific units which were statistically analyzed and generated by Software Prism Graph Pad 8.0.1. T-test and ANOVA experiments were performed to find the significance between the average values of patients and healthy control. All Figures display the parameters that showed a significance. P value was considered P<0.05.

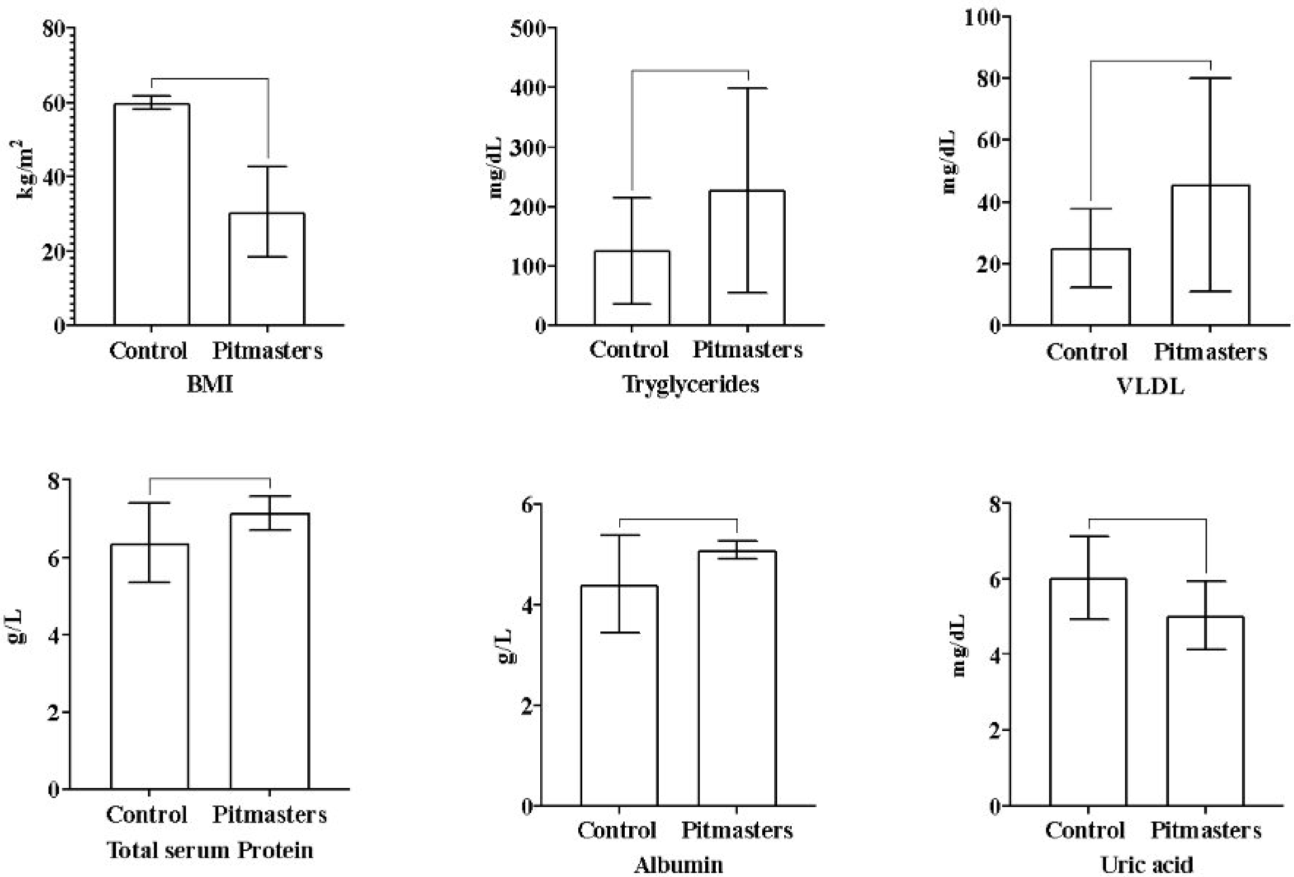

Fig. 2 shows the multiple sub-figures, labeled on bottom of them, for each biochemical parameters examined for pitmasters in comparison to the healthy control. Figures show concentrations' levels or percentage in specific units which were statistically analyzed and generated by Software Prism Graph Pad 8.0.1. T-test and ANOVA experiments were performed to find significance between the average values of patients and healthy control. All Figures display the parameters that showed a significance. P value was considered P<0.05.

Serum uric acid levels were significantly decreased in pitmasters compared with healthy controls. Exposure to grilling emissions may increase carbon monoxide levels in the blood, which could alter purine metabolism and affect uric acid production. It may also influence xanthine oxidase activity, thereby affecting uric acid synthesis. In contrast, decreased uric acid levels may also reflect oxidative stress affecting xanthine oxidase activity. However, the exact mechanism by which inhalation of grilling fumes reduces uric acid levels remains unclear.

Regarding the lipid profile, particularly VLDL and triglyceride levels, both were significantly increased in pitmasters compared with healthy controls. Some studies suggest that smoke exposure may have a limited direct effect on triglycerides, but triglyceride levels may be correlated with body mass index (BMI). In this study, BMI was approximately 25 kg/m^2 and was found to be increased among pitmasters [29–33]. Overall, the results showed significant changes in clinical biomarkers, suggesting that grilling emissions may have harmful effects on BBQ pitmasters.

4 CONCLUSION

BBQ pitmasters are exposed to hazardous fumes during their work, which may affect their health and increase long-term occupational risk. The study results showed that five biochemical parameters out of 15 measured parameters and four hematological parameters out of 10 measured parameters showed significant changes in BBQ workers compared with healthy controls. These changes may be related to unsafe occupational practices followed during grilling.

Therefore, protective measures should be applied to ensure the safety of BBQ workers. Occupational health guidance leaflets should be provided, and warning signs should be displayed for workers and nearby residents who may be exposed to grilling emissions. In conclusion, greater occupational safety efforts are needed to protect BBQ pitmasters from the harmful effects of long-term exposure to grilling fumes.

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Author contributions

All authors mentioned have been collectively contributing to each part of the project. The designer of the study; Manaf A. Guma. Ola.J Jubier and Ali M. Abdul Wahid conducted experiments; Manaf A. Guma and Khaild F. Al-Rawi analyzed the data and discussed the data.

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Data availability

N/A

DECLARATIONS

Conflict of interest

The authors declare no conflict of interest.

Consent to publish

N/A

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