Pakistan J. Zool., pp 1-6, 2024. DOI: https://dx.doi.org/10.17582/journal.pjz/20240209140620

Effect of Graded Levels of Soybean Oil Supplementation as an Energy Source on Broiler Performance, Carcass Characteristics, and Nutrient Digestibility

Abdul Hafeez[1], Hamza Awan[1], Shabana Naz[2], Ibrahim A. Alhidary[3], Rifat Ullah Khan[4]*, Yusuf Konca[5], Shakirullah[6], Hafeez Ur Rahman[6] and Maria Selvaggi[7]

[1]*Department of Poultry Science, Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture, Peshawar, Pakistan*
[2]*Department of Zoology, Government College University, Faisalabad, Pakistan*
[3]*Department of Animal Production, College of Agriculture and Food science, King Saud University, Riadh, Saudi Arabia*
[4]*College of Veterinary Sciences, Faculty of Animal Husbandry and Veterinary Sciences, The University of Agriculture, Peshawar, Pakistan*
[5]*Department of Animal Science, Faculty of Agriculture, University of Erciyes 38039 Melikgazi-Kayseri-Turkiye*
[6]*Livestock Management, Faculty of Veterinary and Animal Sciences, Gomal University, Dera Ismail Khan*
[7]*Department of Soil, Plant and Food Science, University of Bari, Aldo Moro, Via Amendola 165/A, 70125 Bari Italy*

Article Information
Received 09 February 2024
Revised 05 April 2024
Accepted 18 April 2024
Available online 05 July 2024 (early access)

Authors' Contribution
AH, HA: conceptualization
SN, IAA: drafting and resourcing
RUK, YK: methodology
Shakirullah, HUR: Analysis
MS: Proof reading

Key words
Soybean oil, Broilers, Nutrients digestibility, Digestive organs

ABSTRACT

The present study aimed to investigate the impact of soybean oil supplementation at varying levels as an energy source in broiler feed on performance, digestive organ size, and nutrient digestibility. One hundred and eighty-day-old broiler chicks were divided into four groups: S0 (control), S2.5, S5, and S7.5. Each group comprised three replicates with 10 birds in each, with Group S0 serving as the control. Groups S2.5, S5, and S7.5 were provided diets containing soybean oil at levels of 2.5%, 5%, and 7.5%, respectively. While feed intake was not significantly affected during the starter phase, supplementation at 5% and 7.5% resulted in higher intake during the finisher phase and overall period. Weight gain was significantly higher in the 5% soybean oil group during both the starter and finisher stages, along with a lower feed conversion ratio (FCR). Liver and gizzard weights were also higher in the 5% and 7.5% soybean oil groups. Interestingly, apparent total digestibility (ATD%) of dry matter was higher in the control and 2.5% soybean oil groups compared to the 5% and 7.5% groups, while crude fat digestibility was notably higher in the 5% soybean oil group. Overall, supplementation of soybean oil at 5% may be recommended for improved growth performance and crude fat digestibility in broilers feed formulation.

INTRODUCTION

Soybean oil is one of the most widely utilized cooking oils, with vegetable oil being the second most common. It serves as a primary source of cost-effective oil and high-quality protein (Rani *et al*., 2021). The typical composition of soybean includes 36% protein, 20% fat, 30% carbohydrates, 9% water, and 5% ash content (Corke *et al*., 2004). It boasts the highest protein content among food crops. Plant sterols extracted from soybean oil serve as a rich source of cholesterol. Soybean oil comprises five significant fatty acids, notably: 10% palmitic acid (16:0), 4% stearic acid (18:0), 18% oleic acid (18:1), 55% linoleic acid (18:2), and 13% linolenic acid (18:3). Due to the high proportion of linoleic acid and linolenic acid, soybean oil is prone to oxidative instability (Indiarto and Qonit, 2020). Hydrogenation can mitigate this issue for both food and feed applications, reducing polyunsaturated fatty acids to less than 18% of total fatty acids and linolenic acid to below 2% (Bhandari *et al*., 2020). This process results in an increase in the percentage of Stearic acid and oleic

* Corresponding author: rifatullahkhhan@gmail.com
0030-9923/2024/0001-0001 $ 9.00/0

acid. However, the utilization of soybean oil in food and industrial applications is restricted due to its low oxidative stability stemming from the fatty acid composition, leading to rancidity. Rancidity results in off-flavors in food products (Canakci *et al*., 1999; Guo *et al*., 2023).

Several studies have examined the effects of soybean supplementation in poultry diets. For instance, Ali *et al*. (2001) found that broilers fed diets supplemented with varying percentages of soybean oil exhibited higher weight gain between days 30 and 45. Conversely, Anjum *et al*. (2004) reported that the inclusion of oxidized soybean oil in broiler diets resulted in reduced growth performance in terms of weight gain. However, the addition of antioxidants such as ethoxyquin to both oxidized and non-oxidized soybean oil in feed showed positive effects on bird performance (Anjum *et al*., 2002). While some literature has documented beneficial effects of soybean oil supplementation in poultry diets, further investigation is needed to understand its potential positive impacts at different stages of broiler growth. Thus, the present study aimed to evaluate the effects of graded levels of soybean oil supplementation as an energy source on broiler performance, carcass characteristics, and nutrient digestibility.

MATERIALS AND METHODS

Birds and treatments

From standard hatchery a total of 180-day old broiler chicks (male) were purchased. The chicks were randomly distributed into four groups (S0, S2.5, S5, and S7.5) and every group consisted of 3 replicates having 10 birds in every replicate.

Group S0 was offered basal diet formulated without inclusion of soybean oil. Group S2.5 was offered diet containing soybean oil at 2.5% as energy source. Similarly, Group S5 and S7.5 were reared on feed containing soybean oil at 5% and 7.5%, respectively. Throughout the experiment, standard protocols for broiler production were adopted and *ad libitum* watering and feeding practice was followed. All diets were formulated isocaloric (3050 kcal/kg) and isonitrogenous (21.9%). The current study was carried out for 6 weeks. Feed formulations are given in Tables I and II.

Performance parameters

Birds were weighed at the end of every week, while feed intake was measured daily and the data was used to calculate feed conversion ratio (FCR).

Carcass characteristics

On day 42, at the end of trial, 2 birds per replicate were killed by exsanguination after weighing and stunning. Internal organs of the broiler birds were extracted out. Dressing percentage was determined after removing internal organs keeping only the muscular part of the broiler. The weight of the heart, liver, gizzard, spleen and preventiculus was measured separately.

Table I. Feed formulation of starter phase.

Name of ingredient	Starter 2.5%		Starter 05%		Starter 7.5%	
	IR %	Weight (g)	IR %	Weight (g)	IR %	Weight (g)
Maize	54.58	546	51.64	516	48.70	487
SBM 44%	21.50	215	21.5	215	21.50	215
Canola meal	5.00	50	5.0	50	5.00	50
APC 50%	5.00	50	5.0	50	5.00	50
Rice polish	4.00	40	4.0	40	4.00	40
RSM	2.88	29	3.32	33	3.76	38
Soyabean oil	2.50	25	5.00	50	7.50	75
Guar meal	1.50	15	1.50	15	1.50	15
Lime stone	1.00	10	1.00	10	1.00	10
Lysine sulphate 70%	0.52	5.20	0.52	5.20	0.52	5.20
DCP 17%	0.50	5.00	0.50	5.00	0.50	5.00
DLM 99%	0.27	2.70	0.27	2.70	0.27	2.70
Salt	0.22	2.20	0.22	2.20	0.22	2.20
Soda	0.15	1.50	0.15	1.50	0.15	1.50
Choline chloride	0.075	0.75	0.07	0.75	0.075	0.75
L-Threonine	0.072	0.72	0.07	0.72	0.072	0.72
Mineral premix	0.05	0.50	0.05	0.50	0.05	0.50
Vitamin premix	0.05	0.50	0.05	0.50	0.05	0.50
Salinomycine	0.05	0.50	0.05	0.50	0.05	0.50
Toxin free/Tox-in binder	0.05	0.50	0.05	0.50	0.05	0.50
Lincomycine	0.013	0.13	0.013	0.13	0.013	0.13
Sun phase/ phytase	0.013	0.13	0.013	0.13	0.013	0.13
NSP/ Crezyme	0.007	0.07	0.007	0.07	0.007	0.07
Total	100	1000	100	1000	100	1000

SBM, soyabeans meal; APC, alfalfa protein concentrate; RSM, rape see meal; DCP, dicalcium phosphate; DLM, DL-methionine; NSP, Non-starch polysaccharide.

Assessment of parameters for nutrient digestibility

To assess nutrient digestibility, four birds per replicate were transferred to individual experimental cages to collect fecal samples on day 35 of the trial. The gathered samples were then analyzed for dry matter (DM), ash, crude protein (CP), crude fiber (CF), and ether extract (EE) using standard procedures.

Digestibility of apparent metabolizable energy

To quantify the apparent metabolizable energy

(AME), a bomb calorimeter (BC) standardized with benzoic acid was employed. For the AME calculation, the pelleted sample was incinerated in the bomb calorimeter. The formula below was utilized to estimate the apparent metabolizable energy on a dry matter basis:

$$\text{AME} = (\text{Energy consumption} - \text{Energy lost}) \div \text{Feed consumption}$$

Table II. Feed formulation of finisher phase.

Name	Finisher 2.5%		Finisher 05%		Finisher 7.5%	
	IR %	Weight (g)	IR %	Weight (g)	IR %	Weight (g)
Maize	51.88	519	49.15	491	46.21	462
SBM 44%	18.50	185	18.50	185	18.50	185
Canola meal	4.00	40	4.00	40	4.00	40
APC 50%	4.00	40	4.00	40	4.11	41
Rice polish	8.00	80	8.00	80	8.00	80
C.G	2.50	25	2.77	28	3.00	30
Soyabean oil	2.50	25	5.00	50	7.50	75
Guar meal	4.00	40	4.00	40	4.00	40
Fish meal	1.48	14.84	1.63	16.30	1.75	18
Lime stone	1.30	13	1.11	11.09	1.09	11
Lysine sulphate 70%	0.65	6.50	0.65	6.50	0.65	6.50
Isoleucine	0.03	0.30	0.03	0.30	0.03	0.30
DLM 99%	0.313	3.13	0.313	3.13	0.313	3.13
Salt	0.20	2.0	0.20	2.0	0.20	2.0
Soda	0.20	2.0	0.20	2.0	0.20	2.0
Choline chloride	0.075	0.75	0.075	0.75	0.075	0.75
L-Threonine	0.11	0.11	0.11	0.11	0.11	0.11
Mineral premix	0.07	0.70	0.07	0.70	0.07	0.70
Vitamin premix	0.06	0.6	0.06	0.6	0.06	0.6
Salinomycine	0.05	0.5	0.05	0.5	0.05	0.5
Toxin free/ Toxin binder	0.05	0.5	0.05	0.5	0.05	0.5
Lincomycine	0.013	0.13	0.013	0.13	0.013	0.13
Sunphase/ phytase	0.01	0.10	0.01	0.10	0.01	0.10
NSP/Crezyme	0.007	0.07	0.007	0.07	0.007	0.07
Total	100	1000	100	1000	100	1000

For abbreviations see Table I. CG, corn gluten

Statistical analysis

Statistical analysis of data for all parameters was conducted utilizing SAS software, employing a one-way analysis of variance with a completely randomized design. The differentiation of means was established through Tukey's honest significant difference test.

RESULTS

Table III shows the effect of dietary supplementation of soybean oil as energy source at graded level on feed intake (FI), weight gain and feed conversion ratio (FCR) in broilers. Feed intake was not affected (*P*>0.05) at week-1, 2, 3 starter phase and week-4 among all groups. At week-5 and 6, FI was higher in S5 and S7.5 groups in comparison with S0 and S2.5 groups. The same trend was observed at finisher phase and for overall period, where FI was higher

Table III. Effect of dietary supplementation of soybean oil as energy source at graded level on feed intake (FI, g), weight gain (WG, g) and feed conversion ratio (FCR) in broilers.

Groups	S 0	S 2.5	S 5	S 7.5	SEM	P-value
Feed intake (g)						
Week-1	129	131	131	130	0.531	0.519
Week-2	335	330	329	329	0.990	0.071
Week-3	546	541	540	538	1.319	0.272
Starter (d 1-21)	1010	1002	1000	998	1.729	0.069
Week-4	862	850	853	849	2.025	0.099
Week-5	981^{b}	987^{b}	999^{a}	1003^{a}	2.501	<0.001
Week-6	1084^{b}	1080^{b}	1116^{a}	1129^{a}	5.606	<0.001
Finisher(d21-42)	2926^{b}	2916^{b}	2968^{a}	2980^{a}	7.556	<0.001
Overall(d1-42)	3936^{b}	3918^{b}	3968^{a}	3978^{a}	6.883	<0.001
Weight gain (g)						
Week-1	109	113	112	115	0.862	0.112
Week-2	272	270	269	269	1.224	0.898
Week-3	371^{b}	375^{b}	404^{a}	378^{b}	3.753	<0.001
Starter (d 1-21)	752^{b}	758^{b}	785^{a}	762^{b}	3.732	0.001
Week-4	489^{bc}	483^{c}	506^{a}	496^{ab}	2.475	<0.001
Week-5	573^{c}	580^{c}	606^{a}	592^{b}	3.520	<0.001
Week-6	634^{c}	633^{c}	681^{a}	658^{b}	5.167	<0.001
Finisher(d21-42)	1697^{c}	1695^{c}	1793^{a}	1746^{b}	10.69	<0.001
Overall(d1-42)	2449^{c}	2453^{c}	2578^{a}	2508^{b}	13.89	<0.001
Feed conversion ratio (FCR)						
Week-1	1.18	1.16	1.17	1.13	0.008	0.211
Week-2	1.24	1.22	1.23	1.22	0.004	0.749
Week-3	1.47^{a}	1.44^{a}	1.34^{b}	1.43^{a}	0.014	<0.001
Starter (d 1-21)	1.34^{a}	1.33^{ab}	1.27^{c}	1.31^{b}	0.007	<0.001
Week-4	1.76^{a}	1.76^{a}	1.69^{b}	1.71^{b}	0.009	<0.001
Week-5	1.71^{a}	1.70^{a}	1.65^{b}	1.69^{a}	0.007	0.001
Week-6	1.71^{a}	1.71^{a}	1.64^{b}	1.72^{a}	0.008	<0.001
Finisher(d21-42)	1.73^{a}	1.72^{ab}	1.66^{c}	1.71^{b}	0.007	<0.001
Overall(d1-42)	1.61^{a}	1.60^{ab}	1.54^{c}	1.59^{b}	0.007	<0.001

Means without similar superscripts in same row are significantly different at P < 0.05. SO, without soyabean oil; 52.5, 55 and 57.5, with soyabean oil at 2.5%, 5% and 7.5%, respectively.

(P<0.05) in S5 and S7.5 groups in comparison with S0 and S2.5 groups.

WG was not significantly affected at week-1 and week-2 among all groups. At week-3, it was higher (P<0.05) in S5 group as compared to other groups. On the same pattern, at starter phase WG was higher in S5 group as compared to other groups. At week-4, WG was higher (P<0.05) in S5 than S0 and S2.5 groups; whereas WG at S7.5 was higher (P<0.05) than S2.5 group. At week-5 and 6, the WG in S5 group was higher (P<0.05) in comparison with S7.5 group followed by S0 and S2.5 groups. Similar trend was observed at finisher stage, and for the overall period, observed where WG was higher (P<0.05) in S5 (2578±16.0) group in comparison with S7.5 (2508±9.43) group followed by S0 (2449±16.3) and S2.5 (2453±16.1) groups.

As for the FCR in broilers it was similar (P>0.05) among all groups at week-1 and week-2. At week-3, FCR was lower in S5 compared to S0, S2.5 and S7.5 groups. Same trend was followed at starter phase. Additionally, in S7.5 group it was lower than S0 group. At week-4, FCR in S5 and S7.5 was lower (P<0.05) as compared to S0 and S2.5. At week-5 and 6 FCR in S5 group was lower (P<0.05) in comparison with S0, S2.5 and S7.5 groups. At finisher phase and overall period FCR was lower (P<0.05) in S5 group as compared to S2.5 and S7.5 group followed by S0 (1.73±0.01) group.

Table IV shows effect of inclusion of soybean oil as energy source at graded level on digestive organs weight and ATD in broilers. Dressing (%) as well as weight of heart, spleen and proventiculus was not affected (P>0.05) among groups. Liver and gizzard weight, were recorded higher (P<0.05) in S5 and S7.5 groups as compared to S0 and S2.5 groups.

The ATD% of DM was higher (P<0.05) in S0 and S2.5 groups as compared to S5 and S7.5 groups. The ATD% of ash, CP and crude fiber was significantly not affected (P>0.05) among groups. The ATD% of crude fat was higher (P<0.05) in S5 group as compared to other groups.

DISCUSSION

The findings of current experiment revealed that dietary supplementation of soybean oil as energy source at graded level had no significant effect on feed intake at starter phase in broilers. However, at finisher phase as well as for overall period of trial, feed intake was higher in group supplemented with soybean oil at 5% and 7.5% as compared to 2.5% and control group. The findings of our study align with previous studies by Tabeedian *et al*. (2005), who observed higher feed intake in broilers fed a diet supplemented with soybean oil, along with a higher level of protein than the recommended NRC level. However, our results contrast with those of Ali *et al.* (2001), who found that including soybean oil at 10% in the diet significantly reduced feed intake compared to control groups. Anjum *et al*. (2002) also reported no significant effect on feed intake when including 2% oxidized and 2% non-oxidized soybean oil in feed. Similarly, Dvorin *et al.* (1998) suggested that decreasing dietary fat saturation in soybean oil-supplemented diets led to decreased feed intake. Firman *et al*. (2010) found that while broilers fed a high-energy diet with soybean oil at the starter phase did not show any effect on feed intake, intake was reduced at the finisher phase. Another study by Anjum *et al.* (2004) indicated no significant effect on feed intake when including fresh soybean oil at 2% in the diet compared to oxidized soybean oil. Additionally, Chae *et al*. (2002) reported no effect on feed intake in broilers when including fresh or oxidized soybean oil in the diet. The reason for the increased feed intake observed in our study during the finisher phase and overall period is not clear and appears to be anomalous. However, some previous studies have suggested that including soybean oil in broiler diets may increase metabolizable energy levels, ultimately resulting in decreased feed intake.

Table IV. Effect of dietary supplementation of soybean oil as energy source at graded level on digestive organs weight (g) and apparent total digestibility (ATD) of nutrients (%) in broilers.

Groups	S0	S2.5	S5	S7.5	SEM	P value
Digestive organs weight (g)						
Dressing (%)	62.8	62.8	63.0	62.1	0.264	0.703
Heart	9.75	10.25	9.75	9.88	0.182	0.754
Liver	48.6[b]	49.3[b]	51.8[a]	52.1[a]	0.362	<0.001
Gizzard	45.0[b]	45.5[b]	48.5[a]	48.6[a]	0.392	<0.001
Spleen	2.94	3.18	2.96	3.09	0.050	0.297
Proventriculus	8.03	8.18	8.33	8.29	0.107	0.776
Apparent total digestibility (ATD) of nutrients (%)						
DM	74.4[a]	74.2[a]	71.8[b]	70.7[b]	0.366	<0.001
Ash	46.1	46.5	45.8	47.1	0.307	0.495
CP	64.7	65.2	64.4	65.1	0.406	0.909
Crude fiber	47.2	46.8	48.1	47.1	0.311	0.427
Crude fat	76.8[b]	78.6[b]	80.8[a]	78.5[b]	0.363	<0.001

Means without similar superscripts in same row are significantly different at P<0.05. For details of groups, see Table III. DM, dry atter; CP, crude protein.

The current trial found that during the starter phase, broilers supplemented with soybean oil at 5% had higher weight gain compared to other groups. Similarly, during the finisher phase and overall period, the group supplemented with 5% soybean oil showed higher weight gain compared to those supplemented with 7.5% soybean oil, 2.5% soybean oil, and the control group. This aligns with previous study by Ali *et al*. (2001), who reported lower weight gain in broilers fed with 10% soybean oil compared to those fed with lower levels. Nobakht *et al*. (2011) also found higher weight gain with 4% soybean oil supplementation in broilers, while Nitsan *et al*. (1997) reported increased weight gain with 3% soybean oil supplementation. However, Firman *et al*. (2010) found no effect on weight gain with soybean oil supplementation during the starter phase but a slight reduction during the finisher phase. Other studies, such as those by Anjum *et al*. (2002) and Dvorin *et al*. (1998), reported varying effects on weight gain depending on factors like the type of soybean oil used or the level of dietary fat saturation. Additionally, Barbour *et al*. (2006) and Jalali *et al*. (2015) found increased weight gain with soybean oil supplementation under certain conditions. The improved weight gain with 5% soybean oil supplementation in the current study may be attributed to the higher content of linoleic acid and PUFA present in soybean oil. Furthermore, the stabilizing effect of PUFA levels could explain why higher weight gain was observed at 5% inclusion compared to 7.5%.

The present trial demonstrated that during the starter and finisher phases, as well as overall, dietary supplementation of soybean oil at 5% resulted in lower feed conversion ratio compared to all other groups. Similarly, supplementation at 7.5% resulted in lower feed conversion ratio than the control group during these phases. This aligns with previous research by Ali *et al*. (2001), who found better feed efficiency with 4% and 6% soybean oil supplementation compared to 2% and 10% at the finisher period in broilers. Nitsan *et al*. (1997) and Franco *et al*. (1996) also reported improved feed conversion with 3% soybean oil supplementation in broiler feed. Firman *et al*. (2010) found improved feed efficiency with high-energy diets using soybean oil during the finisher phase, and Nobakht *et al*. (2011) reported improved feed efficiency with 4% soybean oil in broiler diets. Other studies, such as those by Anjum *et al*. (2004), reported lower feed conversion ratio with soybean oil supplementation, and Dvorin *et al*. (1998) suggested improved feed conversion with decreased fat saturation in soybean oil diets. Additionally, Jalali *et al*. (2015) found better feed conversion with soybean oil supplementation along with L-carnitine. The literature suggests that improved feed efficiency with soybean oil supplementation in broiler diets may be attributed to factors such as increased fat digestion due to the high content of PUFA in soybean oil. However, feed efficiency may decrease at higher inclusion rates, possibly due to poorer energy utilization.

The current trial found that while dressing percentage, heart, spleen, and proventriculus weight were not affected by soybean oil supplementation in broiler feed, the weight of the liver and gizzard was higher in groups supplemented with 5% and 7.5% soybean oil compared to those with 2.5% soybean oil and the control group. Limited studies are available regarding the effect of soybean oil inclusion on organ weight in broilers. Anjum *et al*. (2004) reported higher liver weight with oxidized soybean oil compared to fresh soybean oil, and a study by L'estrange *et al*. (1966) similarly found increased liver weight with oxidized soybean oil supplementation. The increased liver weight may be attributed to the accumulation of dietary oxidative products. Oxidation can begin through autoxidation or photosensitized oxidation processes, where unsaturated lipids combine with oxygen in complex free-radical processes when exposed to light.

The data from the present study revealed that dietary supplementation of soybean oil did not significantly affect the % ATD of ash, CP, and CF in broilers. However, the % ATD of DM was higher in the control group and the group supplemented with 2.5% soybean oil compared to groups with 5% and 7.5% soybean oil. On the other hand, the % ATD of crude fat was higher in the group supplemented with 5% soybean oil compared to all other groups. There is currently no available literature discussing the impact of soybean oil supplementation on nutrient digestibility in broilers. The higher digestibility of crude fat observed in the present study may be attributed to the high content of PUFA in soybean oil. As PUFA levels increase up to a certain threshold and then stabilize, it is possible that the crude fat digestibility increased up to the 5% inclusion rate of soybean oil and then either decreased or stabilized.

CONCLUSION

In conclusion, supplementing broiler feed with 5% soybean oil significantly improved feed intake, weight gain, and feed conversion ratio compared to other inclusion levels and the control group. Additionally, soybean oil supplementation at different levels did not significantly affect the weight of digestive organs or intestinal length, while crude fat digestibility was notably higher with 5% soybean oil supplementation.

DECLARATIONS

Acknowledgments

We extend our appreciation to the Researchers Supporting Project (No. RSPD2024R833), King Saud University, Riyadh, Saudi Arabia.

IRB approval

The study was approved by the Institutional Board on Animal Welfare and Rights, The University of Agriculture, Peshawar (No. 132/FAHVS/2021).

Ethical statement

The ethicS approval was obtained from Ethical Committee, Faculty of Animal Husbandery and Veterinary Science, The univeristy of Agriculture, Peshawar.

Statement of conflict of interest

The authors have declared no conflict of interest.

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