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Proximate and Functional Properties of Different Sorghum Varieties Produced in Somali Regional State Ethiopia

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ABSTRACT

Sorghum is one of the staple food or crop that widely consumed in Somali community. The study was conducted in Somali Regional state with objective to analyze proximate, functional and physical of different sorghum varieties produced in Somali reginal state. Six different types of samples such as Dekeka, AdoKaye, ESH-1, Melkam, ASSO-1 and JLM control as control sample were collected. The collected sorghum samples were individually grounded to a fine powder (30 mesh size), packed in air tight polyethylene plastic bags and were stored at 4°C until further analysis. Proximate composition such as crude protein, crude fat, crude fiber, moisture content, carbohydrate, total energy, different minerals like calcium, iron, magnesium and total phosphorous were determined by AOAC. The functional and physical properties of the sorghum were determined different standard procedures. Based on the result all locally adapted those sorghum varieties adapted by the Somali region research institute were better in both macro and micro nutrients especially when it comes fiber, total ash, moisture content as compared to the control sample with brand name JLM control which imported from abroad. All samples's protein content is very low which in the range 5.23 to 6.50%. There is significant different in different components of sorghum between different varieties at $p < 0.05$. Significance difference were also observed at $p < 0.05$ in minerals content such as calcium, zinc, iron and total phosphorous. The functional and physical properties of different sorghum varieties under study are almost not significantly different at $p < 0.05$. Overall, from the finding we conclude that, almost all locally adapted sorghum varieties have better in nutritional content especially moisture, ash and fiber and very poor in protein content. Therefore, all actors on sorghum should apply fortification especially bio-fortification to enhance the nutrient content in particular the protein content as sorghum is one of the staple crops in Somali region.

Key Words: Functional Properties, Physical properties, Proximate composition, Sorghum.

1. Introduction

Sorghum is a significant cereal crop globally, with Africa leading in production, accounting for approximately 29.7 million tonnes according to 2017 FAOSTAT data (Milla & Osborne, 2021). It thrives in various climates, primarily in tropical, subtropical, and temperate regions (Visarada & Aruna, 2019), and is believed to have originated from Northeast Africa (Konietzny & Greiner, 2003). Other members of the Poaceae family, such as millet, barley, teff, and wheat, share similar ecological adaptability and resilience to adverse environmental conditions (Adebo, 2020; Linder et al., 2018). The diversity within the sorghum species is notable, with over 20 known varieties (Ratnavathi et al., 2016).

In African nations, particularly in developing countries, sorghum serves as a vital food source, with over 78% of production allocated for human consumption, 14% for animal feed, and 7% for other uses (Batey, 2017). Previous studies have reported variations in the proximate composition of sorghum, with protein content ranging from 6.2% to 14.9%, carbohydrates from 54.6% to 85.2%, fat from 1.3% to 10.5%, ash from 0.9% to 4.2%, and fiber from 1.4% to 26.1%. These variations may be attributed to genotype differences, growth conditions, and other cultivar- specific factors (Hulse et al., 1980).

Sorghum is rich in essential minerals such as potassium (K) and phosphorus (P), vital for muscle function, nervous system health, and bone strength (Zhao et al., 2019). Globally, sorghum ranks as the fourth major cereal in terms of production, with an annual volume exceeding 60 million metric tons cultivated across over 40 million hectares of

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land. Over 500 million people in Africa, Asia, and Latin America rely on sorghum as a staple food (Henley et al., 2010).

Ethiopia emerges as a key player in sorghum production, ranking seventh worldwide and third in Africa, contributing 12% and 5% of annual African and global production, respectively. Sorghum constitutes about 18% of Ethiopia's total grain crop production and occupies 16% of the country's arable land allocated to grains, including cereals, pulses, and oilseeds (CSA, 2012). In Ethiopia, sorghum holds the position of the third most important staple cereal after teff and maize (Latimer Jr, 1920).

Sorghum plays a crucial role in the lives of millions of Ethiopians, serving as a staple food source and utilized in various forms such as injera, bread, porridge, infant food, syrup, and animal feed. Additionally, sorghum stalks find application in construction and fuelwood (Latimer Jr, 1920). Research efforts, particularly within the Somali region, have focused on developing sorghum varieties with specific traits like disease resistance, malt quality, and earliness. However, despite these efforts, comprehensive nutritional profile data for these varieties remains lacking. Given the significant impact of biotic and abiotic factors on sorghum quality worldwide (Horwitz, 1925), this study aims to profile the nutritional, anti- nutritional, mineral, functional, and physical properties of sorghum varieties adapted and released by SoRPARI and grown across different regions of the Somali region in Ethiopia. There are many studies conducted by previous researchers like It thrives in various climates, primarily in tropical, subtropical, and temperate regions (Visarada & Aruna, 2019), and sorghum stalks find application in construction and fuelwood (Latimer Jr, 1920). the significant impact of biotic and abiotic factors on sorghum quality worldwide (Horwitz, 1925), Bulk density was determined by weighing 50 g of sorghum grains and dropping them into a graduated glass measuring cylinder from a constant height (approximately 30 cm).

The volume occupied by the sorghum samples was recorded, and bulk density was calculated as the ratio of grams to milliliters (Dicko et al., 2006). The mineral contents were determined following the procedure outlined in AOAC (Shewale & Pandit, 2011). observed among some sorghum samples, likely attributed to variations in variety, farm management, agroecology, soil fertility, and other factors. This finding aligns with previous research conducted by (Onimawo et al., 2003; Tasie & Gebreyes, 2020) on sorghum grown in Ethiopia. However, it contradicts studies conducted by (Treviño-Salinas et al., 2021) in Mexico. Sorghum bicolor is considered one of the most important food crops in the world, it provides the staple food of a large population in Africa (FAO, 2006).

Sorghum and millets are commonly eaten with the hull which retains the majority of the nutrients, which makes them to be highly nutritious but has inferior organoleptic quality due to the presence of anti-nutritional factors such as tannins and phylates. Tannins and phytates complex with protein and iron, thereby inhibiting protein digestibility and absorption of iron, but this can be overcome by adequate process techniques. Such as sprouting and fermentation (Singleton et al., 1999). Processing methods such as cooking, soaking, sprouting and fermentation have been reported to improve the nutritional and functional properties of plant seed (Jirapa et al., 2001). The sprouting process is known as a way to promote changes in the biochemical, sensual, and nutritional characteristics of cereal grains (Masood et al., 2014). All determinations were made in triplicate. The detection limits for the metal aqueous solution were determined before the real analysis. A recovery study of the analytical procedure was carried out according to the method of Onimawo et al. (2003). Though studies had been conducted in this issue previously by researchers few have addressed these issues properly, therefore, researcher has found the research gaps in order to carry out this study.

2. Materials and Methods

2.1. Materials and Equipment Used

Five different sorghum varieties, namely Dekeka, AdoKaye, ESH-1, Melkam, and ASSO-1, produced or adapted under SoRPARI, were collected from the Dolo-Ado research center. Additionally, one widely marketed variety, JLM-Control, was obtained from the local market in Jigjiga to serve as the control for this study. Only whole sorghum grains free from physical damage or insect infestation were selected for analysis. Equipment for sample preparation was sourced from SoRPARI laboratories, with any missing equipment supplemented by local institutes. Upon arrival at the laboratory, the sorghum samples were individually ground into a fine powder (30 mesh size), packed in airtight polyethylene plastic bags, and stored at 4^0C until further analysis.

2.2. Proximate Composition

The proximate composition of sorghum flours was analyzed following standard AOAC methods (Horwitz, 1925). Moisture content was determined gravimetrically using a hot air oven set at 105^0C until a constant weight was achieved. Ash content was measured using a muffle furnace at 550^0C. Crude protein content was assessed utilizing the Kjeldahl method, with a conversion factor of 6.25 applied. Analysis of crude fat was conducted through solvent extraction. Total carbohydrate content was calculated by the difference between the sum of moisture, ash, protein, and lipid contents. Gross energy content was calculated using Atwater's conversion factors: 16.7 KJ/g (4 kcal/g) for protein, 37.4 KJ/g (9 kcal/g) for fat, and 16.7 KJ/g (4 kcal/g) for carbohydrates, as specified by AOAC guidelines (2000). The results were expressed in calories.

2.3. Mineral Analysis

The mineral contents were determined following the procedure outlined in AOAC (Shewale & Pandit, 2011). Specifically, calcium, iron, and zinc were analyzed using AOAC 2000 official methods 985.35, employing an Atomic Absorption Spectrophotometer. Phosphorus content was determined utilizing the official method 986.24, employing a calorimetric method with ammonium molybdate. Hundred-kernel weight and bulk density measurements were also conducted. For the hundred-kernel weight, one hundred sorghum kernels were randomly selected and individually weighed. Bulk density was determined by weighing 50 g of sorghum grains and dropping them into a graduated glass measuring cylinder from a constant height (approximately 30 cm). The volume occupied by the sorghum samples was recorded, and bulk density was calculated as the ratio of grams to milliliters (Dicko et al., 2006; Kumar et al., 2017).

2.4. Oil and Water Absorption Capacity Determination

$2g$ of the samples was mixed with 10ml of distilled water for 5 $minutes$ respectively on a magnetic stirrer. The mixture was centrifuged at 3500 rpm for 30 $minutes$ and the volume of the supernatant was measured by using 10ml measuring cylinder on each of the sample. The water density was taken to be 1g/ml.

$$WAC = Weight\ of\ the\ sample\ used \times 100$$

2.5. Statistical Analysis

All the analysis was performed in duplicate (unless stated otherwise) and presented as mean $\pm$ standard deviation. The statistical significance of the data obtained was analyzed by One-way analysis of variance (ANOVA) followed by the Duncan test using Genstat version 18.0. The level of significance was considered at $p < 0.05$.

3. Results and Discussion

3.1. Results

The proximate composition of different sorghum varieties has been depicted in Table 1. Melkam variety has the lowest in moisture content while Adokaye is the highest. No significance difference was observed between Melkam, Asso-1, Dekeka varieties of sorghum under study at $p < 0.05$. JLM control has the lowest in ash content while Melkam has the highest. When it comes crude fiber content, Melkam has the highest while (Ash-1 and Dekeka) has the lowest. The crude fiber content was significantly different between Melkam and (Ash-1 and Dekeka) & JLM control sample at $p < 0.05$. With respect to crude protein content, Melkam has the lowest while Asso-1 variety has the highest in crude protein content. There is no significance difference in between JLM control, Adokaye and Esh-1 samples at $p < 0.05$. Dekeka has the lowest while Esh- 1 has the highest in crude fat content. The crude fat content was significantly different among all varieties of sorghum under study at $p < 0.05$.

When it comes carbohydrate content, all sorghum varieties have high amount of carbohydrate as shown in Table 1. Dekeka variety has the highest while Esh-1 has the lowest in carbohydrate content. There is no significant difference in carbohydrate among Asso-1, Esh-1, Adokaye and JLM control samples at $p < 0.05$. There is also no significance difference in between Melkam and JLM control samples. The energy in calory unit were also calculated and depicted as shown in Table 1 above. Adokaye variety has the lowest while Esh-1 has the highest in energy obtained from consuming $100g$ of each sample. The energy obtained is significantly different in between Esh-1 and Adokaye at $p < 0.05$. Significant difference was also in between (Esh-1 & Adokaye) varieties and the rest of others sorghum varieties under study at $p < 0.05$.

Minerals are important in fighting against hidden hunger or micronutrient deficiency. The calcium content in the range of 900mg/Kg to 1401mg/kg for sorghum sample JLM control and Eshi-1 respectively. The calcium content is significantly different between Asso-1 and the rest of others sorghum varieties under study at $p < 0.05$. When it comes zinc content different sorghum varieties, it is in the range of 32.39 mg/Kg to 40.42 mg/Kg for JLM control and Melkam sample respectively. No significant difference in zinc content were observed in between Adokaye, Dekeka and Asso-1 varieties at $p < 0.05$. The iron content of different sorghum varieties is also indicated in Table 2. The iron content in the range of 67.9mg/Kg to 180.1mg/Kg for JLM control sample and Melkam sorghum sample respectively.

Significant difference was observed in iron content in all sorghum varieties under study at $p < 0.05$. The total phosphorous content is also indicated in Table 2. In a similar fashion JLM control has the lowest (2600mg/Kg) while Melkam sorghum sample has the highest in total phosphorous sample which is 4200mg/kg. Significant difference was observed in total phosphorous content of all sorghum varieties under study at $p < 0.05$.

The functional properties of different crops or food types are important in determining the integration of food with oil, water and other ingredients. Water absorbing capacity in the range of 1.075 to 1.640 for Esh-1 and JLM control samples respectively. No significant difference was observed in water absorbing capacity among all sorghum samples except JLM control samples which is significantly different at $p < 0.05$ as indicated above. When it comes to oil absorbing capacity, it is in the range from 0.6050 to 1.1900 for Adokaye and Melkam sorghum samples respectively. The oil absorbing capacity is not significantly different among all sorghum samples as indicated above at $p < 0.05$.

Table 4: Physical properties of different sorghum varieties

Varieties	100 seed weight (g)	Bulk density (g/ml)
JLM Control	3.645 ± 0.23^b	0.760 ± 0.01^b
AdoKaye	3.045 ± 0.31^a	0.695 ± 0.02^a
Dekeka	2.800 ± 0.24^a	0.750 ± 0.02^b
ESH-1	2.975 ± 0.26^a	0.770 ± 0.03^{bc}
Asso-1	2.855 ± 0.30^a	0.685 ± 0.01^a
Melkam	3.005 ± 0.34^a	0.785 ± 0.03^c

Key: Same letter in the same column is not significantly different from each other at $p < 0.05$.
JLM: The control sorghum sample.

The different physical properties are also important as quality indicators for different crop types. The 100 seed

Table 1: Proximate composition of different Sorghum varieties

Varieties	Results in (%) (100g)						
	Moisture	Ash	C.Fiber	C.Protein	C.Fat	CHO	Energy
JLM Control	11.61 ± 0.24^{cd}	2.330 ± 0.01^{a}	2.720 ± 0.11^{b}	6.320 ± 0.24^{bc}	6.570 ± 0.14^{c}	70.45 ± 0.31^{ab}	366.2 ± 0.55^{b}
AdoKaye	12.51 ± 0.11^{d}	2.910 ± 0.02^{b}	2.840 ± 0.02^{bc}	6.210 ± 0.23^{b}	5.500 ± 0.23^{b}	70.03 ± 0.46^{a}	354.5 ± 0.98^{a}
Dekeka	9.63 ± 0.22^{ab}	3.110 ± 0.11^{bc}	2.410 ± 0.03^{a}	6.490 ± 0.11^{c}	5.165 ± 0.31^{a}	73.19 ± 0.34^{c}	365.2 ± 0.87^{b}
ESH-1	10.65 ± 0.12^{bc}	3.260 ± 0.21^{cd}	2.410 ± 0.12^{a}	6.240 ± 0.12^{bc}	8.270 ± 0.25^{f}	69.17 ± 0.12^{a}	376.1 ± 0.94^{c}
Asso-1	10.07 ± 0.31^{ab}	3.410 ± 0.08^{d}	2.910 ± 0.03^{bc}	6.500 ± 0.21^{c}	7.270 ± 0.34^{e}	69.84 ± 0.48^{a}	370.8 ± 0.84^{bc}
Melkam	9.36 ± 0.23^{a}	3.830 ± 0.10^{e}	3.000 ± 0.14^{c}	5.230 ± 0.14^{a}	6.940 ± 0.26^{d}	71.64 ± 0.51^{b}	369.9 ± 0.96^{bc}

Key: Same letter in the same column is not significantly different from each other at $p < 0.05$.
JLM: The control sorghum sample.
CHO: Carbohydrate,
Energy: Energy in Calory unit obtained from consuming 100g of these sorghum varieties

Table 2: Minerals content of different Sorghum varieties

Varieties	Results in (mg/kg)			
Varieties	Calcium	Zinc	Iron (Fe)	Total Phosphorous
JLM Control	900 ± 2.50^{a}	32.39 ± 0.98^{a}	67.9 ± 0.92^{a}	2600 ± 8.85^{a}
AdoKaye	1200 ± 3.65^{b}	34.83 ± 0.96^{b}	100.4 ± 0.98^{b}	3300 ± 8.95^{b}
Dekeka	900 ± 4.24^{a}	34.16 ± 0.86^{b}	127.4 ± 1.24^{c}	3600 ± 7.95^{c}
ESH-1	1401 ± 6.55^{d}	37.50 ± 0.94^{c}	160.7 ± 1.55^{d}	4100 ± 9.96^{e}
Asso-1	1300 ± 6.75^{c}	33.45 ± 0.92^{ab}	175.8 ± 2.08^{e}	3800 ± 9.02^{d}
Melkam	1400 ± 7.01^{d}	40.42 ± 0.97^{d}	180.1 ± 2.21^{f}	4200 ± 9.13^{f}

Key: Same letter in the same column is not significantly different from each other at $p < 0.05$
JLM: The control sorghum sample

weight is in the range of 2.800g to 3.645g for Dekeka and JLM control sorghum samples respectively. When it comes bulk density, it is in the range of 0.685g/ml to 0.785g/ml for Asso-1 and Melkam sorghum samples respectively. The bulk density of Melkam sample is significantly different as compared to other sorghum samples under study except Esh-1 sample at P<0.05.

3.2. Discussions

3.2.1. Proximate composition/Macronutrient/ of different sorghum varieties

The proximate composition of different sorghum varieties is presented in Table 1. Significant differences in moisture content were observed among some sorghum samples, likely attributed to variations in variety, farm management, agro-ecology, soil fertility, and other factors. This finding aligns with previous research conducted by (Onimawo et al., 2003; Tasie & Gebreyes, 2020) on sorghum grown in Ethiopia. However, it contradicts studies conducted by (Treviño-Salinas et al., 2021) in Mexico. The results confirm that the sorghum varieties tested were not affected by mold growth or wetness-related damage, likely due to a moisture level below 15% (Onimawo et al., 2003).

The ash content of different sorghum varieties ranged from 2.33% to 3.83%. Significant differences were observed among some sorghum varieties (Table 1), possibly due to variations in variety, farm management, soil fertility, and other factors. This result contradicts findings from studies conducted by (Treviño-Salinas et al., 2021) in Mexico, and (Tasie & Gebreyes, 2020) in Ethiopia. The higher ash content observed in Somali region sorghum samples may be attributed to the virginity and fertility of the soil.

Significant differences in fiber content were also observed among different sorghum varieties, likely influenced by variety type and farm management practices. The fiber content of the six varieties studied was lower compared to findings from studies conducted by (Treviño-Salinas et al., 2021) in Mexico, and (Tasie & Gebreyes, 2020) in Ethiopia. This may be due to the higher ash, moisture, and carbohydrate content of these varieties, indicating a need for interventions such as biofortification. Protein content ranged from 5.23% to 6.50% among different sorghum samples in this research (Table 1), with significant differences observed. Variations in protein content may be attributed to differences in variety, farm management, and other factors.

The protein content of these six varieties was relatively lower compared to findings from studies conducted by (Treviño-Salinas et al., 2021), and (Tasie & Gebreyes, 2020). This suggests a need for interventions such as biofortification to enhance the nutritional value of sorghum. Fat content ranged from 5.165% to 8.270% among the sorghum varieties studied (Table 1), with significant differences observed ($p < 0.05$). Variations in fat content may be attributed to differences in variety types, seed origin, farm management practices, and other factors. This

Table 3: Functional Properties of different Sorghum varieties

Varieties	Water Absorbing Capacity (w/w)	Oil Absorbing Capacity (w/w)
JLM Control	1.640 ± 0.02^b	0.9150 ± 0.03^a
AdoKaye	0.875 ± 0.04^a	0.6050 ± 0.05^a
Dekeka	1.080 ± 0.03^a	0.6900 ± 0.04^a
ESH-1	1.075 ± 0.03^a	0.6250 ± 0.06^a
Asso-1	0.850 ± 0.02^a	1.0500 ± 0.09^a
Melkam	0.930 ± 0.04^a	1.1900 ± 1.01^a

Key: Same letter in the same column is not significantly different from each other at $p < 0.05$.
JLM: The control sorghum sample.
WAC = Water Absorbing Capacity, OAC = Oil Absorbing Capacity

finding aligns with the results of (Tasie & Gebreyes, 2020) for sorghum grown in Ethiopia, but contradicts findings from studies conducted by (Treviño-Salinas et al., 2021) in Mexico. Carbohydrate content varied among sorghum varieties, with significant differences observed (Table 1). Variations in carbohydrate content may be attributed to differences in variety type and macro components such as protein, fat, moisture, fiber, and ash. The results are consistent with findings from studies conducted by (Tasie & Gebreyes, 2020) in Ethiopia but contradict those of (Treviño-Salinas et al., 2021) in Mexico. Energy content, calculated using standard factors for carbohydrate, fat, and protein, ranged from 354.5 kcal to 376.1 kcal. Significant differences in energy content were observed among some sorghum varieties ($p < 0.05$), likely due to variations in macro components and variety types.

3.2.2. Mineral's content of different sorghum varieties

The calcium content of sorghum varieties ranged from 900 mg/kg to 1401 mg/kg. Significant differences in calcium content were observed among some sorghum varieties in this research ($p < 0.05$), likely due to variations in variety, soil fertility, and farm management. These findings are consistent with research conducted by (Idris, 2002) in Sudan. Zinc content ranged from 32.38 mg/kg to 40.42 mg/kg across different sorghum varieties (Table 2). Significant differences in zinc content were observed among some sorghum varieties ($p < 0.05$), possibly influenced by variety, soil fertility, and farm management practices. Iron content varied from 67.9 mg/kg to 180.1 mg/kg among sorghum varieties, with significant differences observed across all varieties in this research. Variations in iron content may be attributed to differences in variety, soil fertility, and farm management. Phosphorus content ranged from 2600 mg/kg to 4200 mg/kg (Table 2), with significant differences observed among all sorghum varieties in this research. Variations in phosphorus content may be attributed to differences in variety, soil fertility, and farm management practices. These results contradict findings from research conducted by (Idris, 2002)in Sudan, possibly due to differences in ash content, agro- ecological conditions, soil fertility, and other factors.

3.2.3. Functional Properties

The water and oil absorbing capacities of the sorghum varieties exhibited no significant differences in their interactions with oil and water, except for the control sample. Water absorption capacity (WAC) refers to the flour's ability to absorb water and swell, thereby enhancing food consistency (Twinomuhwezi et al., 2020). The slight variations observed in water absorption capacities among different sorghum varieties may be attributed to differences in protein concentrations, their interaction with water, and conformational characteristics (McWatters et al., 2003). Oil absorption capacity serves as an indicator of the rate at which proteins bind to fat in food formulations (Twinomuhwezi et al., 2020). It is a crucial functional property that enhances mouthfeel and retains flavors in food products, playing an important role in food formulation (McWatters et al., 2003). The oil absorption capacities of the flour samples varied among the different sorghum varieties, as indicated in Table 3 above. However, statistical analysis revealed no significant difference ($p < 0.05$) in the oil absorption capacity of the flour samples.

3.2.4. Physical properties

The physical properties of different sorghum varieties are summarized in Table 4. There were some significant differences observed between different sorghum varieties in terms of bulk density. The variations in bulk density may be attributed to the intrinsic characteristics of each variety. Density values play a crucial role in the design of silos and storage bins. Regarding hundred-seed weight, significant differences were observed, with values ranging from 2.855 to 3.645 g. Low hundred-seed weight may be indicative of low moisture content, which increases the likelihood of more damaged grains during milling. In comparison to other researchers, our findings generally align with the importance of bulk density in storage facility design and the impact of moisture content on seed weight and milling quality. However, specific comparisons with other studies would require further analysis of their methodologies and results.

3.2.5. Conclusion

The research was done on six sorghum varieties of which one is a control sample. From the data obtained we conclude that, the moisture content of all varieties below 15% which is an indication for their better shelf stability. The ash content of all sorghum varieties is high which an indication for their high mineral content. The fiber, carbohydrate and fat content of all sorghum varieties are also high enough. But the protein content of all sorghum varieties is very low. When it comes to minerals content, all varieties of sorghum have high amount calcium, iron, zinc and total phosphorous. Significant different were observed in all varieties for both macro and micro nutrients. Therefore, we recommend, Further research and bio-fortification or any other ways of fortification to all sorghum varieties.

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Conflict of Interest

Authors declare that there is no conflict of interest involve in publishing this research paper.

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