DLG Test Report 6168 F

CLAAS Selbstfahrende Erntemaschinen GmbH

CLAAS JAGUAR 960

Moisture measurement in maize with an NIR sensor on the forage harvester's discharge spout

DLG FOKUS TEST

11/13 Moisture measurement in maize

Test Center
Technology and Farm Inputs

www.DLG.org

Overview

The Focus Test is a DLG usability test intended to allow product differentiation and special highlighting of innovations in machinery and technical products used primarily in agriculture, forestry, horticulture, fruit cultivation and viticulture, as well as in landscape and municipal management. This test focuses on testing a product's individual qualitative criteria, e.g. fatigue strength, performance, or quality of work.

The scope of testing can include criteria from the testing framework of a DLG Signum Test, the DLG's extensive usability test for technical products, and concludes with the publishing of a test report and the awarding of a test mark.

In the DLG Focus Test "Moisture measurement in maize", the data obtained on the harvested crop's moisture content with dry matter sensors is compared with the results of dry matter determination according to the official reference method, and an assessment is made of the agreement between the resulting pairs of values.

The DLG test was conducted during the 2013 harvest season with a mobile CLAAS NIR sensor (model year: 2014) installed on the discharge spout of a CLAAS Jaguar 960.

In order to cover as broad a range of applications as possible, chopping was conducted at two locations (Lower Saxony and Brandenburg) with four maize varieties with different levels of dry matter content.

Several truckloads were harvested of each maize variety and the sensor data relating to their moisture content was recorded. Then, during unloading at the silo, representative composite samples were taken from each truckload and submitted for laboratory analysis.

The reference value determined with the official method for each truckload was compared with the corresponding sensor data, and the absolute deviation was determined.

Furthermore, the accuracy of yield measurement with the CLAAS QUANTIMETER was also examined in the test using reference weighings on a calibrated vehicle scale.

Other criteria were not investigated.

Assessment – Brief Summary

Overall, the measurements obtained with the mobile CLAAS NIR sensor on the forage harvester's discharge spout showed good agreement with the official reference method for moisture determination in maize over a broad range of dry matter levels from 21 % DM to 40 % DM. In 36 of 38 reference measurements, the observed deviation lies within a tolerance range of less than 2 % (absolute) between the sensor value and laboratory value, as defined for the assessment, and none of the deviations are greater than 3 % (absolute). In 23 of 36 values pairs – or 64 % of all value pairs – the deviation in the dry matter content indicated by the sensor is no greater than 1 $\%_{abs}$.

Furthermore, 95 % of the values lie within the 2 $\%_{abs}$ deviation.

The mobile CLAAS NIR sensor on the forage harvester's discharge spout therefore satisfies the requirements for the DLG Focus Test "Moisture measurement in maize".

Table 1:
Overview of the results of the "Moisture measurement" field trial

Overall result*	Individual results for four levels of dry matter content				
	Maize variety	Number of loads	DM content acc. to reference method [%]	DM content acc. to sensor measurement [%]	Average deviation [$\%_{abs}$ DM]
23 VP: < 1 $\%_{abs}$	Diamantis	12	37.1 [35.0–39.7]	37.6 [35.1–40.4]	0.5
13 VP: 1 to 2 $\%_{abs}$	P 9027	11	32.0 [29.8–34.2]	31.2 [30.5–31.5]	0.7
2 VP: 2 to 3 $\%_{abs}$	P 8327	10	28.5 [27.0–30.7]	27.6 [26.8–28.6]	0.9
(VP = value pair)	Kimberley	5	22.5 [20.8–23.6]	23.0 [21.9–24.7]	0.6

* Number of value pairs (VPs) from a total of 38 reference analyses with a deviation of % $_{abs}$ DM (absolute dry matter deviation)

Manufacturer and Applicant

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Product:
CLAAS JAGUAR 960
with NIR sensor and
CLAAS QUANTIMETER

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Description and Technical Data

Functional principle of the NIR sensor (near-infrared sensor)

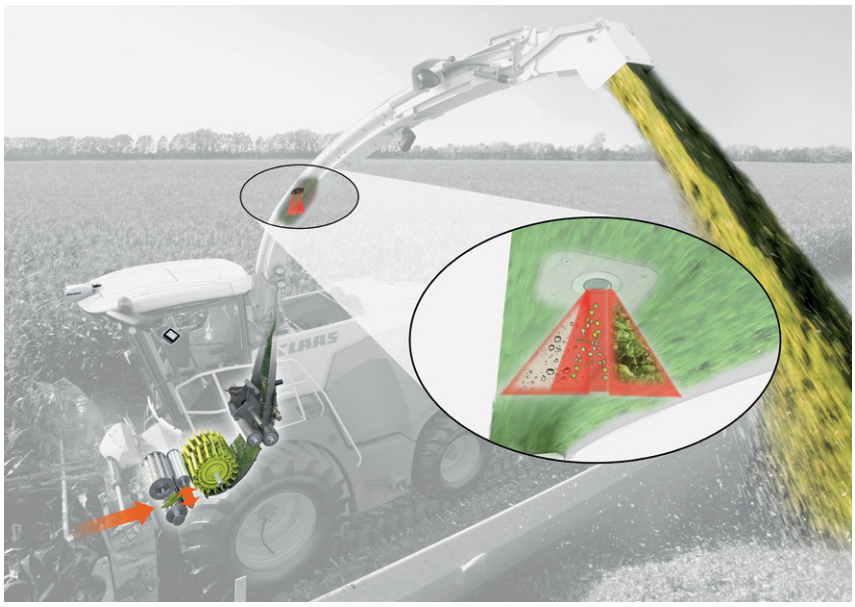

Figure 2:
CLAAS NIR sensor on the forage harvester's discharge spout, functional diagram (CLAAS product photo)

For the sensor used in the test to measure moisture, the measurement principle is based on near-infrared spectrometry (NIR). The measurement process runs continuously throughout the harvesting process without affecting the forage harvester's crop flow. In the discharge spout, a light source fires a beam of radiation at the harvested crop as it flows past. The way this beam is reflected varies depending on how moist the harvested crop is.

The analyser unit detects the reflected portion and breaks it down into its constituent spectrum. The measured spectrum is compared with a saved calibration model that is optimised for the selected crop type. The corresponding DM content is determined from this. The calibration models are based on numerous prior analyses of harvested-crop samples. There is no need for the operator to calibrate the system.

A measurement is taken 20 times a second in order to achieve a high level of measurement accuracy. The forage harvester's CEBIS on-board information system uses these measurements to output the average value once a second. The average DM content can be called up on a field-by-field basis via the job counter information.

Figure 3:
Measuring-head unit on the discharge spout (CLAAS product photos)

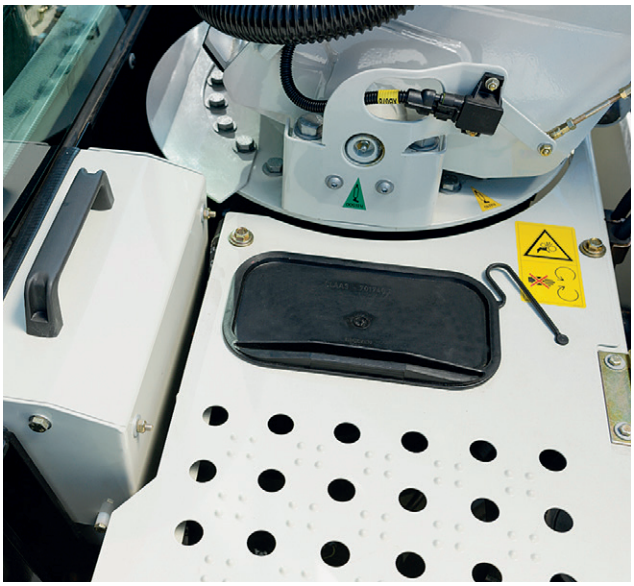

Figure 4:
Analyser unit on the rear side of the driver's cabin (CLAAS product photo)

Forage harvester

The forage harvester used in the test was a CLAAS Jaguar 960 with an ORBIS 750 AC TS Pro 10-row maize header with a working width of 7.5 m.

The forage harvester is driven by a Mercedes Benz engine with a capacity of 16 litres and a power of 480 kW (653 HP) according to ECE R 120 at 1,800 rpm. The exhaust gas is post-treated by the well-known SCR system (Selective Catalytic Reduction).

The engine is installed at right angles to the driving direction. The chopper unit, the Corn Cracker and the crop accelerator are driven directly via the power band.

Other features include the "V-MAX" knife drum, stepless cutting-length adjustment and hydraulic discharge-accelerator adjustment. The standard features also include the CEBIS on-board information system, which also monitors and documents the NIR sensor's data. This allows job management on a field-by-field basis in order to record the area treated per hour, the fuel consumption and the crop quantity with respect to fresh and dry matter.

Figure 5:
CLAAS Jaguar in field operation (CLAAS product photo)

The Method

In the DLG Focus Test "Moisture measurement in maize", a field trial was conducted in order to test the mobile CLAAS NIR sensor installed on the discharge spout of a CLAAS Jaguar 960. The machine was equipped with a "VMAX 24" knife drum and a CLAAS MULTI CROP CRACKER (MCC). In the test, the forage harvester's basic settings were based on the local harvesting conditions and were determined in preliminary tests. The chopping length was set to 8 mm, the crop accelerator was set to 10 mm and the Corn Cracker was set to 1.8 mm. The "DYNAMIC POWER" engine characteristic control was activated. The harvester was driven in first gear without all-wheel drive. These settings remained unchanged throughout the measurement runs.

The aim of the DLG Focus Test "Moisture measurement in maize" is to determine the accuracy of mobile dry matter sensors for dry matter determination in maize in comparison to the official reference method (drying-cabinet method). In order to cover as broad a range of applications as possible, the trials are conducted with different maize varieties with at least three different levels of dry matter content. In each version of the trial, at least 10 truckloads are harvested and the data on the average dry matter content is documented for each load using the mobile NIR sensors on the discharge spout. After unloading at the silo, a representative composite sample is produced from each truckload using a sufficient number of samples (see Figures 7 to 9). The composite sample produced in this way is then homogenised. At least three representative subsamples are then produced from each homogenised composite sample and transferred to suitable containers. The fresh matter sample weight is determined and documented directly at the time of filling. The containers are sealed, labelled and kept refrigerated on a temporary basis. Three subsamples from each truckload are

Figure 7 to 9:
Sample taking and sample processing at the silo

used to determine the dry matter using the official method in the contract laboratory. The mean value for the dry matter content is determined as a reference value according to the official method from the laboratory values for the three subsamples from each truckload. These mean values from the laboratory analysis are compared with the corresponding data from the mobile dry matter sensors, and the absolute deviations between the sensor data and reference values are calculated for the resulting value pairs of dry matter content data. In addition, the DLG test included an analysis of the recording accuracy of the forage harvester's yield using the CLAAS QUANTIMETER. For this purpose, the crop quantity of each individual load is determined using a calibrated vehicle scale. The reference values obtained in this way are compared with the output value from the forage harvester's on-board information computer, and the absolute deviations and coefficient of determination are determined for the value pairs.

The Test Results in Detail

Table 2:
Overview of the maize varieties and trial locations

Maize variety	Description of variety	Crop	Yield [t FM/ha]*	Trial location	Number of loads	DM [%]**
P 9027	Dent maize, medium early – medium late Silage maize ripeness rating ~260 Maize grain ripeness rating ~260 PIONEER Hi-Bred	Homogeneous Plant height approx. 3.5 m Number of cobs 1–2 Row spacing 75 cm	Approx. 53.4	Lower Saxony	11	32.0 [29.8–34.2]
Diamantis	Intermediate type, medium early Silage maize ripeness rating ~250 Maize grain ripeness rating ~250 Euralis Saaten GmbH	Homogeneous Plant height approx. 3.5 m Number of cobs 1–2 Row spacing 75 cm	Approx. 51.4	Lower Saxony	12	37.1 [35.0–39.7]
P 8327	Dent maize, medium late FAO 270 Silage maize ripeness rating ~270 Maize grain ripeness rating ~ 270 PIONEER Hi-Bred	Less homogeneous Plant heights 3–3.5 m Number of cobs 1–2 Row spacing 75 cm	Approx. 48.7	Brandenburg	10	28.5 [27.0–30.7]
Kimberley	Dent maize, late Silage maize ripeness rating ~300 Maize grain ripeness rating ~320 Saaten-Union GmbH	Less homogeneous Plant heights 2.5–3.2 m Number of cobs 1–2 Row spacing 75 cm	Approx. 46.6	Brandenburg	5	22.5 [20.8–23.6]

Harvesting conditions

The field test was conducted in the 2013 harvest season at two locations in northern Lower Saxony and Brandenburg. Two trial areas, cultivated with different maize varieties, were available at each trial location. In total, four maize varieties with different levels of dry matter content were harvested in the DLG test (see Table 2).

At the trial location in northern Lower Saxony, the maize crops were relatively homogeneous with growth heights of approx. 3.5 m and fresh matter yields between 51 t/ha and 54 t/ha. The crops available for the test in Brandenburg were less homogeneous, with growth heights of 2.5 to 3.5 m and yields of 46 t/ha FM to 49 t/ha FM.

Figures 10 and 11:
Harvesting conditions on a trial area in Lower Saxony

* Determined from harvested loads / ** According to official reference method

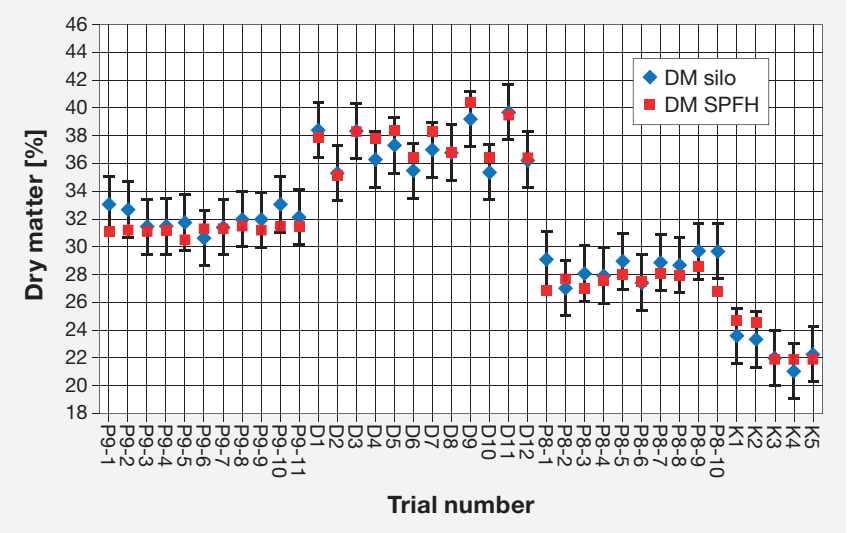

Figure 12:
Comparison between the DM content indicated by the CLAAS NIR sensor and the reference values determined according to the drying-cabinet method

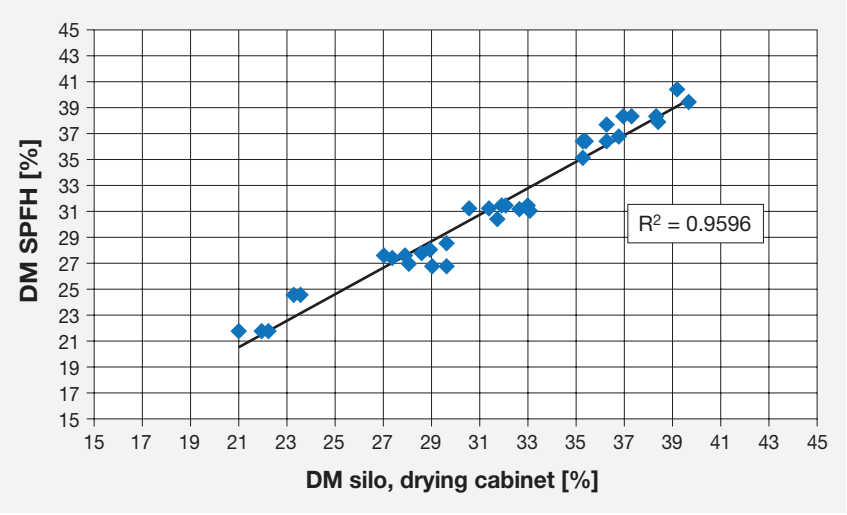

Figure 13:
Correlation between the DM values indicated by the NIR sensor (DM SPFH) and the laboratory values determined from sampling at the silo

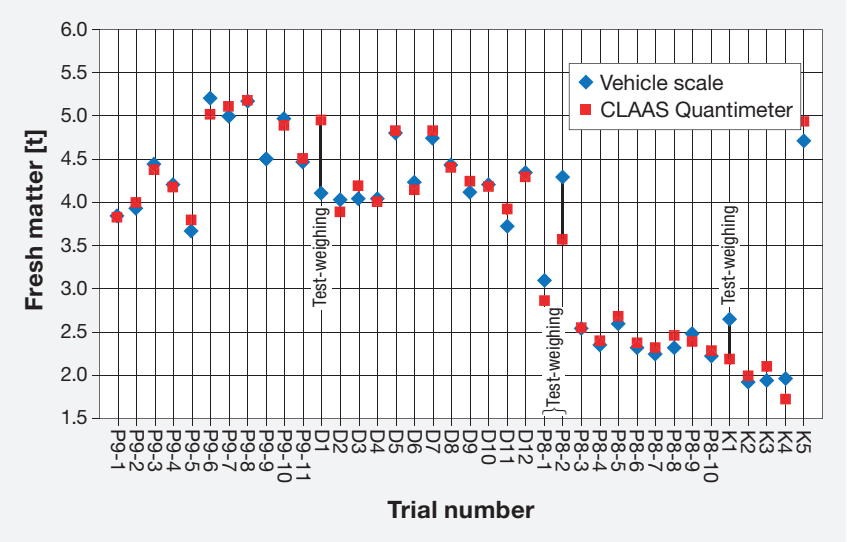

Figure 14:
Comparison of the weights outputted by the vehicle scale and the CLAAS QUANTIMETER

Dry matter determination with the CLAAS NIR sensor

Figure 12 shows the deviations of the dry matter content determined by the NIR sensor from the reference values determined with the official method. In total, 38 eligible trial runs were conducted with four maize varieties at the two locations. In the graph, the measured values from the dry matter sensor are shown in red and the results from the laboratory analysis are shown in blue. Each reference value from the laboratory analysis is assigned a tolerance range of +/- 2 $\%_{abs}$ in the graph.

The sensor value's deviation lies within a tolerance range of ≤ 2 $\%_{abs}$ in 36 of 38 value pairs, and none of the deviations exceed a value of 3 $\%_{abs}$. In 23 of 36 value pairs – or 64 % of all value pairs – the deviation in the dry matter content indicated by the sensor is no greater than 1 $\%_{abs}$. Furthermore, 95 % of the values lie within the 2 % deviation. A high degree of agreement is therefore achieved between sensor values and reference values.

Over all measurement runs, this results in a coefficient of determination of $R^2 = 0.96$ (see Fig 13) for the CLAAS NIR sensor values in comparison to the dry matter content from the reference analysis and an average deviation of 0.7 % in the indicated dry matter content across all trialled maize varieties, as well as a broad dry matter range from 21 % DM to 40 % DM.

The mobile CLAAS NIR sensor on the forage harvester's discharge spout therefore satisfies the requirements for the DLG Focus Test "Moisture measurement in maize", and the agreement between the sensor values and reference values can be classified as good according to the DLG assessment scale.

Additional test of yield recording with the CLAAS QUANTIMETER

In addition, the DLG test included an analysis of the recording accuracy of the forage harvester's yield with the CLAAS QUANTIMETER. For this purpose, the crop quantity

of each individual load was determined using a calibrated vehicle scale. The reference values obtained in this way were compared with the output value from the forage harvester's on-board information computer, and the absolute deviations and coefficient of determination were determined for the value pairs. At each change in variety, the trial runs were preceded by a calibration measurement.

The value pairs for each individual load are shown in Figure 14. The calibration factor calculated through test-weighing in measurement run P8-1 was not applied in the CLAAS QUANTIMETER. This led to a large deviation in measurement run P8-2. Following repetition of the test-weighing , consistently good agreement was achieved with regard to crop quantity between the yield measurement and the vehicle scale. Over a total of 38 measurement runs, a total crop quantity of 139.9 t FM was determined with the vehicle scale. The combined yields from the CLAAS QUANTIMETER data gave a value of 140.2 t FM. Without taking into account the calibration runs, there is a difference of around 300 kg DM (corresponding to about 0.2 %) between the total quantity determined with the vehicle scale and the CLAAS QUANTIMETER from 38 measurement runs. Here, the coefficient of determination in the comparison of the CLAAS QUANTIMETER data and the reference value is also R^2= 0.96 (see Figure 15).

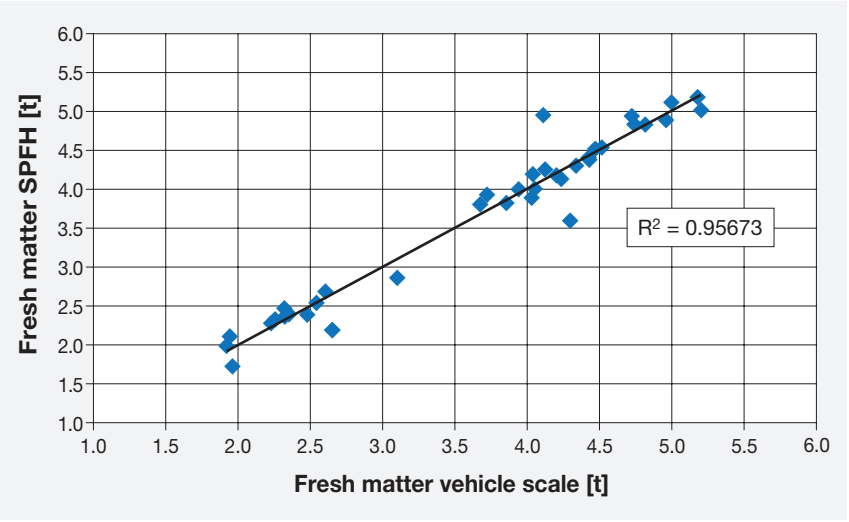

Figure 15:
Correlation between the harvested matter indicated by the SPFH's yield measurement [t] and the fresh matter weights determined with the vehicle scale [t]

Overall, the yield measurement with the CLAAS QUANTIMETER shows good agreement with the reference values using the vehicle scale. This high degree of agreement can only be achieved, however, if test-weighing is carried out for the purposes of calibration when the variety changes, the chopping lengths are changed, or there is strong variation in dry matter content in the crop.

Summary

The DLG Focus Test "Moisture measurement in maize" shows that the measurements obtained with the mobile CLAAS NIR sensor on the forage harvester's discharge spout achieve good agreement with the official reference method for moisture determination in maize over a broad range of dry matter levels from 21 % DM to 40 % DM.

In 36 of 38 reference measurements, the determined deviation in dry matter content between the sensor value and laboratory value does not exceed 2 $\%_{abs}$; moreover, the deviation is less than 1 $\%_{abs}$ in 23 value pairs.

In the DLG test, none of the sensor values exceed the permissible tolerance with a deviation of more than 3 $\%_{abs}$. At 96 %, the coefficient of determination for sensor value vs. laboratory value is at a very high level, and the average deviation between sensor value and reference value is 0.7 %.

The mobile CLAAS NIR sensor on the forage harvester's discharge spout therefore satisfies the requirements for the DLG Focus Test "Moisture measurement in maize", and the DLG test mark was awarded.

Furthermore, an accompanying analysis was made of the yield measurement with the CLAAS QUANTIMETER. A high level of accuracy can also be achieved here if test-weighing is carried out when the variety changes and when the chopping length is changed. For crops with strong variations in dry matter content, regular test-weighing seems to be advisable for checking purposes in order to maintain the high level of accuracy.

Further Information

Further tests on mobile dry matter sensors on forage harvesters can be downloaded from the "Forage Harvester" section at **www.dlg-test.de/ernte**. Within the field of the DLG's technical work, the DLG Committee for Technology in Crop Production deals closely with the topic of harvest technology. Instruction leaflets and documents relating to this technical work, which is carried out on a voluntary basis, are available free of charge in PDF format at **www.dlg.org/technik_pflanzenproduktion.html**

Test execution

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DLG testing framework

Focus Test
"Moisture measurement in maize"

Field

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The DLG

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