MICROBIOLOGICAL ATTRIBUTES OF YELLOW OXISSOL UNDER DIFFERENT MONOCULTURES IN THE SAVANNA REGION OF PIAUÍ STATE

ATRIBUTOS MICROBIOLÓGICOS DE UM LATOSSOLOS AMARELO SOB DIFERENTES MONOCULTURAS NO CERRADO PIAUIENSE

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ABSTRACT: Microbial biomass is an important component in maintaining soil quality and plant productivity. The aim of this paper was to evaluate alterations in microbiological attributes and organic carbon in accordance with seasonal change in different monocultures in the Savanna region of Piauí state. Soil samples were collected in areas of soy, eucalyptus, pasture, and in an area of native savanna, at depths of 0-0.20 m, during the rainy and dry periods. Using these samples microbial biomass carbon (MBC), basal respiration (BR), metabolic quotient (qCO_2), microbial quotient (qMIC), and total organic carbon in the soil (TOC) were evaluated. MBC differed significantly between the systems evaluated, with higher values in the soil under native vegetation in the two sampling periods. TOC presented a significant difference between the systems, with higher values in the native savanna and soybean in the rainy period. For the qMIC, the soybean area presented lower values in the two periods compared with the other areas. Basal respiration as well as qCO_2 values differed between the systems only in the dry period. The results reveal that the type of vegetation cover, management system, and seasonality influence the behavior of biological properties in the soil.

KEYWORDS: Microbial biomass. Seasonality. Organic carbon.

INTRODUCTION

Over the last three decades, the soils of the Savanna region in the state of Piauí have been gradually used for annual cultivations, pasture, and more recently, reforestations. Adequate soil management is a crucial factor to consider when aiming towards a sustainable agricultural system, as soil preparation and cultivation systems interfere in soil quality.

Substituting Savanna forests for agricultural systems causes changes in soil quality attributes, in accordance with the cultivation of species with low nutritional quality, the absence of soil cover, and the type of management, among others (CARNEIRO et al. 2009). Implanting cultivation via conventional management, as in the case of soy, primarily involves soil inversion via plowing and harrowing, with the incorporation of vegetal residues. In this management system, although the contribution to increased performance and productivity is evident, the soil becomes more exposed to the environment, as soil macroaggregates are broken up, resulting in the loss of organic material and reduced biological activity and drastically altering soil quality (DADALTO et al., 2015; COSTA et al. 2006; LEITE et al., 2010).

As for pasture monoculture, we see a large input of organic residues to the decomposer subsystem resulting from constant renewal by the death of grass roots (WENDLING et al., 2005), although extensive animal rearing often causes compacting due to treading. In turn, eucalyptus cultivation, in which soil preparation in the region is limited to one subsoiling and plowing and harrowing for planting, leads to a large quantity of plant litter of low nutritional quality and low coefficient of decomposition (k = 0 , 45), (VIEIRA et al. 2013), favoring the accumulation of organic carbon in the soil (BARRETO et al., 2014).

In order to make any inferences regarding the impact of management practices on soil quality, monitoring of physical, chemical, and biological soil indicators is recommended. Microbial indicators deserve special attention as they show great sensitivity to soil management or environmental pressures, given that microorganisms and their interactions are fundamental to various processes and functions, including decomposition of organic material, nutrient cycling, N mineralization, soil

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structure formation, and pest control (PULEMANN et al., 2012).

Loss of soil biological quality caused by the expansion, intensification, and mechanization of agriculture has been identified as one of the main problems throughout the whole world, due to the suppression of organic material, as well as soil compacting and contamination and climatic alterations from converting natural vegetation into agricultural exploitation systems (CREAMER et al., 2010; GARDI et al., 2009).

The aim of this paper was to evaluate alterations in soil biological indicators, as well as levels of organic material, for different monocultures and periods in dystrophic YELLOW OXISSOL.

MATERIAL AND METHODS

The study was carried out at the Chapada Grande Farm, located in the municipality of Regeneração, PI. It covers approximately 20,000 ha and sits at an altitude of 400 m at the geographical coordinates 06° 14' 16" south latitude and 42° 41' 18" west longitude. The climate, according to the Köppen climatic classification, is of the Aw type (rainy tropical). The region presents an average annual temperature of 26.4 ºC and precipitation with rain spread out between November and May (Figure 1).

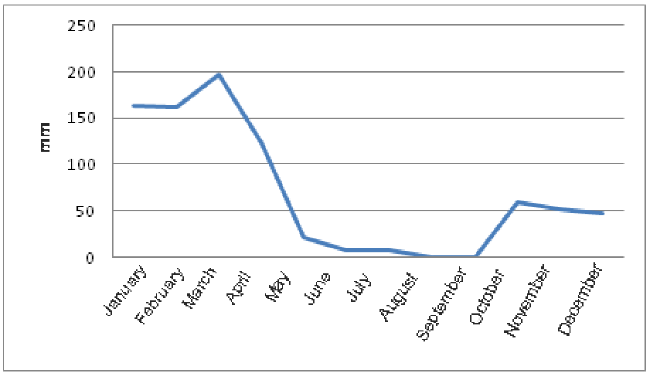

Figure 1. Monthly precipitation in 2015 at the Chapada Grande Farm - PI.

Four areas were selected, based on the criteria of proximity of the desired crops and the presence of the same soil class. The areas cultivated with soybean, pasture and eucalyptus were all established in 2008, and a Cerrado forest was used as a reference (Figure 2).

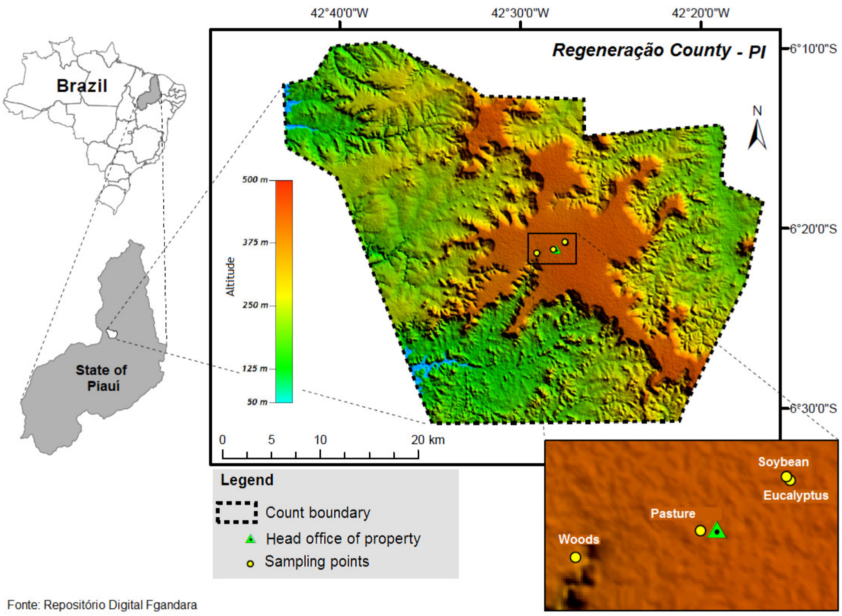

Figure 2. Location of the soil sample collection points at Chapada Grande Farm, Regeneração / PI.

In each area, 100 m^2 geo-referenced plots were outlined for soil collection. The Table 1 shows the history of uses of the areas studied.

Tabela 1. Histórico do manejo e adubação das áreas.

Área	**Histórico**
Soybean	Area cultivated with rice in 2008, and with soybean in the subsequent years. Initial soil preparation consisted of plowing, furrowing, root collection, incorporation of 4 t ha-1 of limestone and fertilization of 250 kg ha-1 of NPK. Conventional management was performed with use of plow and harrow until the year 2013. In 2014, no-tillage was used.
Pasture	Area cultivated with soy under conventional management from 2008. From 2011 it was cultivated with Bachiaria brizanta using identical management to the soy area. Area with capacity for 20 animal units. The pasture is used for cattle for 8 months and is rested for 4 months.
Eucalyptus	Planting of eucalyptus (MA, 2000) after the clearing of savanna forest with windrowing and burning of the branches and leaves. Initial soil preparation consisted of harrowing and furrowing for planting, incorporation of 4 t ha-1 of limestone and 400 kg ha-1 of triple superphosphate. Eucalyptus was planted in 2008, using a spacing of 3.5 x 2.5m. Cover fertilization was carried out with NPK (20-00-20), using 150 kg plant-1. The following operations were performed: subsoiling at the time of soil preparation, manual weeding in the area, 2 months after planting, and harrowing between rows, 3 months after planting. In August 2015, there was an accidental burn, one month before the second soil collection.
Native forest	Area under savanna, with original vegetation and without anthropic interference, used as reference.

The soil in the study area was classified as Dystrophic YELLOW OXISSOL (JACOMINE, 1986) of a clayey texture (Table 2). The soil samples were collected in the months of February and September of 2015 from the 0-0.20 m layer, with 10 repetitions in each area. The samples were conditioned in plastic bags with a respirator and transported in refrigeration in polystyrene boxes with ice to the Soil Analysis Laboratory for subsequent analysis.

Table 2. Granulometric composition of the soils under different monocultures in the 0-0.20 m layer.

System	Granulometry (g kg^{-1})			Textural Class
	Sand	**Silt**	**Clay**	
Depth (0 – 0.20 m)				
Soybean	367	192	441	Clayey
Eucalyptus	224	373	403	Clayey
Pasture	273	219	508	Clayey
Native Savanna	288	280	432	Clayey

Microbial biomass carbon (MBC) was determined using the irradiation-extraction method proposed by Islam; Weil (1998). Total organic carbon (TOC) was determined via oxidation of the organic material with potassium dichromate in the presence of concentrated sulfuric acid (Walkley-Black). Using the MBC and TOC content values, the microbial quotient (qMIC) was calculated by means of the following equation: qMIC = MBC / TOC x 100.

Microbial activity in the soil was evaluated by determining soil respiration, which estimates the quantity of carbon emitted in the form of CO_2 by the respiration of heterotrophic microorganisms in the soil (ALEF et al., 1995). Soil respiration was estimated by quantifying the CO_2 released during seven days of soil incubation in a closed system. The CO_2 produced was captured in a NaOH (1 mol L^{-1}) solution and subsequently titrated with HCL (0.05 mol L^{-1}). The metabolic quotient (qCO_2), which represents microbial respiration per biomass unit

(ANDERSON; DOMSCH, 1993), was determined by the ratio between C-CO_2 released by respiration and MBC.

The data obtained were submitted for variance analysis (ANAVA) and test of means at a 5% level of probability. The R Statistical 7.5 beta package was used. Multivariate principal component analysis (PCA) techniques were also employed to understand how the variables interacted at the same time, using the SAS 9.0 statistical program.

RESULTS AND DISCUSSION

The results obtained in the total organic carbon (TOC) analysis differed between the study areas, with the highest values found in soybean (2.16 g/kg) and native savanna (2.20 g/kg) areas, in the rainy period, and native savanna (2.38 g/kg) and eucalyptus (2.69 g/kg) in the dry period (Table 3). Normally, substituting cerrado vegetation for monocultures causes significant loss of organic carbon to different degrees depending on the soil management.

The higher TOC values in the native savanna area are related with the creeping and arboreal plants in this environment and the constant input and accumulation of vegetal residues (leaves, branches, and roots, for example), of a particular quality (less lignified plant litter), maintaining a stable state in the additions and losses of organic carbon (LOSS et al., 2012; BEZERRA et al., 2013). In relation to the system with soy under direct planting, high TOC values can be explained by the organic residues deposited on the soil surface and soy roots accumulated at shallow depths, which undoubtedly suffered from intense decomposition, given that the wet period favors microbial activity.

Table 3. Microbiological attributes and organic carbon of soils in the management systems studied.

	Soybean	Pasture	Eucalyptus	Native Savanna
Atributes	Rainy period			
TOC	2.16 a	1.48 b	1.80 b	2.20 a
MBC	224.58 b	247.27 b	457.02 a	405.82 a
qMIC	1.06 c	1.67 bc	2.66 a	1.85 b
Microbial Activity	113.08 a	127.85 a	106.98 a	129.93 a
qCO_2	0.67 a	0.65 a	0.54 a	0.56 a
Atributes	Dry period			
TOC	2.14 b	1.98 b	2.69 a	2.38 ab
MBC	167.13 b	170.18 b	213.16 b	267.05 a
qMIC	0.79 b	0.87 ab	0.84 b	1.13 a
Microbial Activity	90.32 a	89.25 a	85.73 a	55.62 b
qCO_2	0.56 a	0.55 a	0.42 a	0.22 b

Averages followed by the same letter do not differ statistically using the Tukey test at 1% probability.
TOC – Total organic Carbon; MBC - Microbial biomass carbon; qMIC - Microbial quotient; qCO_2 – quociente metabólico

The reductions in TOC levels in the system with pasture are associated with inadequate management, especially due to the absence of maintenance fertilizations, and above all, due to overgrazing on the soil, which results in pasture degradation, as also observed by Jakeilats et al. (2008). In turn, the eucalyptus presents organic residues with a high C/N ratio, of 30 to 100, in accordance with the part of the plant studied, and high levels of lignin and polyphenols, which contribute to the slow decomposition of residue (PULRONIK, et al., 2009), and which may have contributed to a reduction in this variable in the wet period. On the other hand, the higher values for this management system in the dry period can be attributed to the fact that a fire occurred in the area before the second soil collection. A study carried out by Nunes et al. (2006) revealed that soils that suffered from fires presented similar TOC values to Caatinga forest.

The highest MBC values were observed in savanna (232.7 mg C g^{-1}) and eucalyptus (199.5 mg C g^{-1}) soils in the rainy period and savanna (267.5 mg C g^{-1}) in the dry period, indicating the occurrence of adverse effects of soybean and pasture monoculture on soil microbial biomass (Table 3). When studying the microbial community in native vegetation soils, relatively higher values are already expected compared to soils with other types of vegetation cover, such as cultivated soils, as microbiota is favored by soil cover that provides a greater accumulation of organic material, providing a greater source of nutrients for microbiota development (ALVES et al., 2011), as well as a continuous supply of organic material, with different degrees of susceptibility to decomposition, originating from the vegetation (CUNHA et al., 2012).

Studies carried out by Cortez et al. (2014) showed that in the fourth year of cultivation eucalyptus can produce up to 5.20 tons of plant litter per hectare, a factor that may have provided certain environmental conditions that favored the maintenance of MBC in equal values to that of the native savanna. However, in the dry period the value of this variable in the eucalyptus did not differ from the soy and pasture. The fire occurring in this area proves that fire causes the destruction of microbial biomass in soil, as this is very sensitive to alterations in the forms of organic carbon in soil. This was proven by Nunes et al. (2006), who when working with ULTISOL found higher biomass carbon values in the natural vegetation and in an area set aside for five years (416 and 438 mg g^{-1} of MBC, respectively), while that of the treatment that suffered from fire presented the lowest value (87 mg g^{-1} of MBC).

On the other hand, the areas with pasture and soy presented lower MBC values in the two periods. Clearing native vegetation reduces plant diversity and has an impact on microbial biomass. This impact can be attributed to differences in the quantity and quality of resources that enter the compartment below the soil in the form of chaff and root exudates, which are nutrient sources for microbial community development. This probably happens because additions of oxidizable carbon in these systems were not enough to meet the energy demands of the existing biomass, which leads to a considerable reduction in this variable.

The variations in soil moisture between the systems and different times studied influenced the behavior of these variables. In the period with the greatest hydric availability in the soil, stimulation of microbial activity was observed, expressed by higher MBC values, and contrasting with the drier period. This supports the suggestion that microbial biomass works as a sensitive environmental variations indicator, as shown in studies carried out by Castelan ; Vidor (1990).

The microbial quotient (qMIC) was influenced by the collection period and decreased between the rainy and dry periods. The highest absolute qMIC values, of 2.6%, were found in the soil in the eucalyptus system in the wet period. This ratio has been reported as an indicator of the quality of organic material in soil and expresses the efficiency of biomass in the face of alterations in soil processes. Agricultural systems that exhibit higher values for this variable indicate more appropriate conditions for microbial development, which can result from the addition of good quality organic material or the absence of a limiting factor (CHAER ; TÓTOLA, 2007).

In this paper, in the wet period the systems with eucalyptus and under native scrub showed values close to the standard (2.2%) considered by Jenkinson & Ladd (1981) as the value in which equilibrium would occur. As for the dry period, the soil under eucalyptus presented a lower absolute qMIC value for the soils under soy and pasture, probably due to the fire. qMIC values lower than 1.0, such as those found in these areas in the period of hydric stress, indicate that the dynamic of organic material is much slower in these systems. Similar results were observed by Nunes et al. (2009) in soils under caatinga that suffered from fires and were cultivated with corn and bean, and by Geraldes et al. (1995) in 15 year old pasture in dystrophic RED-YELLOW OXISOL.

Respiratory activity did not present any difference between the systems studied in the period with good hydric availability. In the dry period the greatest losses of C-CO_2 due to microbial activity occurred in the soy, eucalyptus, and pasture systems, in which there was anthropic action, which could indicate a higher energetic equilibrium in these systems (Table 3). However, other studies have shown that a high value for this variable can be the result of intense oxidizable C consumption by microorganisms for their maintenance, in circumstances in which microbial biomass finds itself under conditions of stress (CORTEZ et al., 2014; ARAÚJO; MELO., 2010). Thus, the higher values in the soy and pasture systems in the dry period appear to be strongly related to temperature, as these areas have little vegetation cover and solar radiation falls directly on the soil in this period. Moreover, the low level of moisture in these soils due to the absence of rain in this period is another determining factor for high respiratory activity in these areas. In turn, in the eucalyptus monoculture the fire occurring in the dry period was undoubtedly detrimental, given that the respiratory rate of the microbiota increased, leading to losses in C in the form of C-CO_2 in this system, as also observed by Balota et al., (2015).

However, in many cases, no differences are detected between degraded and preserved soils when only respiration is evaluated. To interpret these results, the respiration rate per biomass unit was determined, in this case the metabolic quotient (qCO_2), and compared between the systems. No significant differences were observed in this variable between the areas in the rainy season (Table 3). As for the dry season, it is perceived that the greater organic C mineralization activity in the soil occurred in the soy, pasture, and eucalyptus systems, in which there was anthropic action. High qCO_2 values show that management for prolonged monocultures causes soil degradation, especially through the loss of material, as observed by Pascual et al. (2001).

Some studies show that in situations of low soil moisture (Nunes et al., 2009) and high temperatures (RHEINHEIMER et al., 2003), qCO_2 tends to increase, as occurred in the dry period in the anthropized soils. This condition enables a population of opportunistic microorganisms, known as “K” strategists, which present physiological adaptations in their ability to withstand the environment, and consequently show a high reproductive rate, causing greater losses in C in the form of CO_2 in the system (CHAER; TÓTOLA, 2007). Thus, theoretically, the systems with native scrub and eucalyptus, where the input of a large quantity of plant litter would keep the soil moister and with a lower temperature, would have to present lower values for this variable. This did not occur for the eucalyptus due to the fire in the low rainfall period.

The principal components analysis (PCA) was carried out in the data matrix constructed from 5 variables (Figure 3). With regards to the percentage of variance explained by the principal components, it is verified that the first two principal components are responsible for 86.24% of the original variability, with PC1 and PC2 accounting for 57.35% and 28.89%, respectively.

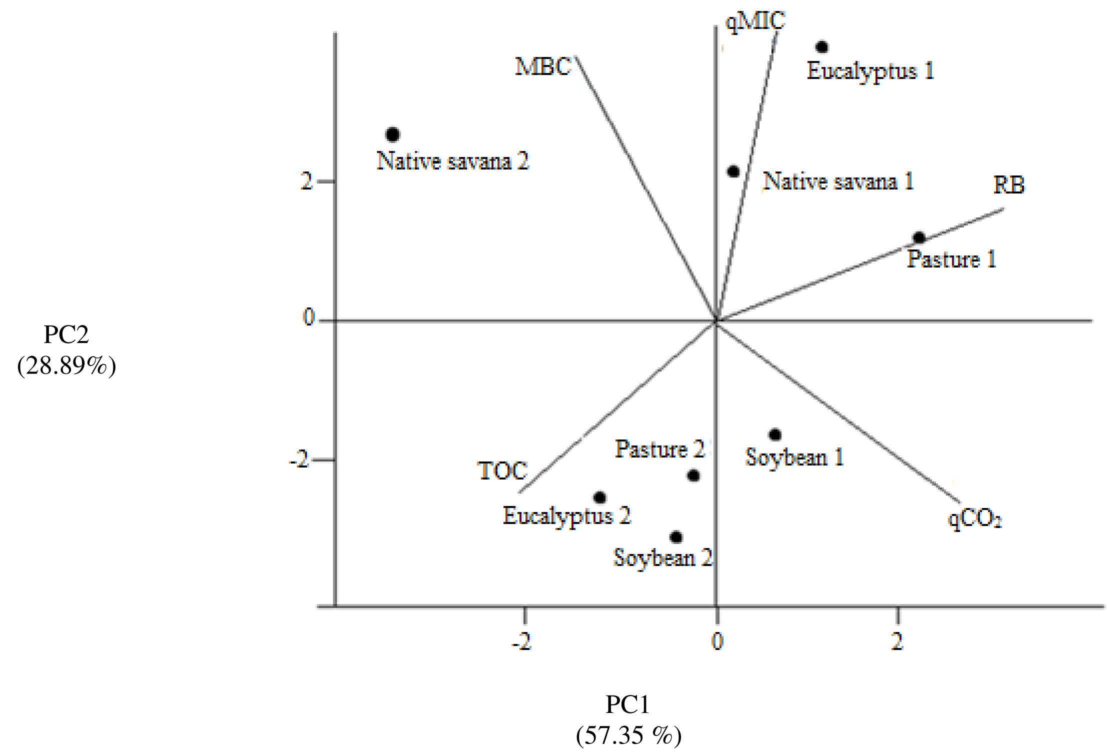

Figure 3. Principal components analysis (PCA) based on the soil variables in the different treatments.
MBC – Microbial biomass carbon, TOC – Total organic carbon; 1 – Rainy period; 2 – Dry period.

The diagram shows that the group comprised of SY 1 fell into the lower right quadrant and had a correlation with qCO_2. The group formed of SY 2, PAS 2, and EP 2 in the lower left quadrant showed an association with organic carbon (TOC). In turn, NS 1, EP 1, and PAS 1 formed a group in the upper right quadrant. It is verified in this group that EP and NS are strongly associated with the qMIC, as is PAS with basal respiration (BR). And finally, NS 2 formed another isolated group in the upper left quadrant associated with MBC.

In these last two groups the main biological variations (MBC and qMIC) were associated with the native scrub in the two periods and eucalyptus in the rainy period, which appears to be related to the greater input of vegetal residue deposited in these treatments. Freitas et al. (2014), by evaluating managed areas and comparing with areas of native vegetation, found a greater relationship between biological variables and areas where there was no anthropic interference and agriculture machinery action, associated with the input of vegetal residues.

CONCLUSIONS

Management systems and vegetation cover influence microbial biomass in soil, resulting in greater biomass in areas under native scrub and eucalyptus.

The different sampling periods influence the microbiological properties of the soil in the systems, with the areas under soy and pasture presenting greater vulnerability to these temporal changes.

The eucalyptus system that suffered from fire contributed to a drastic reduction in the microbiological indicators in the soil.

RESUMO: A biomassa microbiana é um componente importante para manter a qualidade do solo e a produtividade das plantas. O objetivo deste trabalho foi avaliar as alterações nos atributos microbiológicas e carbono orgânico, em função da variação sazonal em diferentes monoculturas no Cerrado piauiense. Amostras de solo foram coletadas em áreas de soja, eucalipto, pastagem e em uma área de mata nativa de Cerrado na profundidade de 0-0,20 m, durante o período chuvoso e seco. A partir dessas amostras avaliaram-se o carbono da biomassa microbiana (CBM), respiração basal (RB), quociente metabólico (qCO_2), quociente microbiano (qMIC) e o carbono orgânico total do solo (COT). O CBM diferiu significativamente entre os sistemas avaliados, com maiores valores no solo sob mata nativa nos dois períodos de amostragem. O COT apresentou diferença significativa entre os sistemas, com maiores valores na mata nativa e soja no período chuvoso. Para o qMIC, a área com soja apresentou menores valores nos dois períodos em comparação às demais áreas. A RB assim como valores de qCO_2 diferiram entre os sistemas apenas no período seco. Os resultados demonstram que o tipo de cobertura vegetal, o sistema de manejo e a sazonalidade influenciam o comportamento das propriedades biológicas do solo.

PALAVRAS-CHAVE: Biomassa microbiana. Sazonalidade. Carbono orgânico.

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