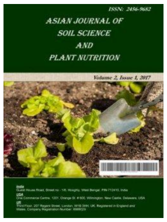

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Isolation and Characterisation of Particulate Organic Matter in Some Soils of Ganges Meander Floodplain and Ganges Tidal Floodplain of Bangladesh

Rikta Khatun[1], Md. Zulfikar Khan[1*] and Md. Sadiqul Amin[1]

[1]*Soil, Water and Environment Discipline, Khulna University, P.O.Box: 9208, Khulna, Bangladesh.*

Authors' contributions

This work was carried out in collaboration between all authors. Author RK designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors MZK and MSA reviewed the study design and all drafts of the manuscript. Authors MZK and RK undertook the statistical analysis of the data collected and managed the literature searches and reference-citations. Finally, all the authors read and approved the final manuscript.

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ABSTRACT

The research was conducted with six representative soil series of Ganges Meander Floodplain and Ganges Tidal Floodplain of Bangladesh during the period of September, 2016 to March, 2017 to isolate and characterise the active fraction of particulate organic matter and its effect on nitrogen and other soil properties. A total 36 soils samples (0-15 cm) were collected in the field through random sampling from six representative soil series of GMF and GTF under different cropping pattern. The laboratory investigation was carried out in the Department of Soil, Water and Environment Discipline, Khulna University, Khulna, Bangladesh. The results indicate that the pH of the studied soils was neutral to mildly alkaline and all the studied soils were non-saline. The active fraction of soil organic matter as well as particulate organic matter was found highest (11.62 g/kg) in Barisal and lowest (2.90 g/kg) in Sara soil series. The highest amount of total nitrogen was found in the soil of Barisal (10.88 g/kg) series and the lowest was in Ishurdi (7.02 g/kg) soil series. In the present study, a positive relationship was found between total nitrogen content and particulate organic matter. The highest amount of micro-aggregate associated carbon at > 0.50 mm range

**Corresponding author: Email: Zulfikar.ku11@gmail.com;*

was found in the soil of Barisal series (11.26 g/kg) and the lowest was in Sara series (2.11 g/kg). The highest amount of micro-aggregate associated carbon in the range of 0.50-0.25 mm was found in Amjhupi series (10.88 g/kg) and the lowest was in Ishurdi series (7.02 g/kg). Total nitrogen content of the soils was positively correlated with POM, SOM, clay, pH but negatively correlated with silt. Moreover, silt and the particulate organic matter is negatively correlated. Soil organic carbon associated with the aggregates of 0.50-0.25 mm size range had a positive correlation with SOM associated with the aggregates of > 0.50 mm size range which is significant at 5% level. The P value between SOC 2 and SOM is significant, while in case of POM it is highly significant at 5% level of significance.

Keywords: Particulate organic matter; soil organic carbon; total nitrogen; micro-aggregate; cropping pattern; soil series and chemical attributes.

1. INTRODUCTION

Soil organic matter (SOM) is an important indicator of soil fertility and productivity because of its crucial role in soil chemical, physical and biological properties [1]. Soil organic matter is made up of plant and animal residues in different stages of decomposition, cells of soil microorganisms, and substances that are so well-decomposed it's impossible to tell what they were to begin with. Living organisms are also considered to be part of soil organic matter, and they play a big role in contributing organic residues to the soil and in formation of more stable types of organic matter. Soil organic matter which occurs as a series of fractions based on decomposition rate affects many soil properties, e.g. soil stabilisation, nutrient cycling, and carbon (C) sequestration [2]. Baldock and Skjemstad [3] grouped SOM into two classes: living and non-living components. Soil organic matter chemistry represents the dynamic interplay between heterogeneous plant inputs, soil organisms, and physiochemical stabilisation processes [4]. Due to this the dynamics of SOM following land-use remain difficult to predict because the complex biological, physical, and chemical mechanisms control C turnover. Soil organic matter consists of a number of fractions ranging from very active (labile) to stable (non-labile). The biologically and physically active particulate organic matter (POM) is part of the labile (easily decomposable) pool of soil organic matter. Active soil organic matter is primarily made up of fresh plant and animal residues that break down in a very short time, from a few weeks to a few years. The particulate organic matter can account for well over 10% of the soil C [1]. Particulate organic matter has been suggested as a sensitive indicator of changes of SOM due to its responsiveness to management practices. The amount of active soil organic matter and the proportion of it makes up of total soil organic matter are good indicators of soil health. Passive soil organic matter, also known as humus, is not biologically active, meaning it provides very little food for soil organisms. It consists primarily of detritus, partially broken-down cells and tissues that are only gradually decomposing. Stabilised organic matter acts like a sponge and can absorb six times its weight in water. In sandy soils, water held by organic matter will make the difference between crop failure or success during a dry year.

In recent years, the stability of organic matter (OM) has gained increasing attention [5]. A new concept has been proposed to make out changes in OM stability which differs from previous approaches by focusing on changes in ^{15}N and C:N ratio. Many other studies have been done related for active fraction of organic matter and its relation with microaggregates and soil nitrogen (N) availability. For decreasing C:N ratio, N-rich organic compounds are increasingly utilised as a C source, while excess N is mineralised, resulting in ^{15}N enrichment of the remaining substrate [6], which is increasingly associated with mineral particles. Soil organic matter can also be differentiated into light and dense fractions on which various researches have done.

The study has a scope to focus on the organic matter with its humified fine fractions of six soil series and relations of soil micro-aggregates with them. Organic carbon is the most deficient element in Bangladesh. Efficient research is needed on the aspect of reducing organic matter loss from the soil and improves organic matter status in the soil. If it is possible to improve organic matter, N use efficiency also improves as more than 85% N comes from the decomposition of organic matter. The 21st century poses a formidable challenge, particularly to the soil scientists. If we can't improve the present condition of soil organic matter we have to address some vital problems in the next. Janzen et al. [7] investigated the changes in the light fraction material (incompletely decomposed organic residues-labile organic matter) over three long-term rotation systems. Respiration rate, microbial N, and N mineralisation are found to be highly correlated with the light fraction content. Therefore, the research was done to isolate and characterise the active fraction of particulate organic matter and its effect on nitrogen and other soil properties in some soils of Ganges meander floodplain and Ganges tidal floodplain.

2. MATERIALS AND METHODS

A laboratory investigation with six representative soil series of Ganges Meander Floodplain and Ganges Tidal floodplain of Bangladesh was carried out to isolate and characterise the active fraction of soil organic matter and its effect on nitrogen and other soil properties.

2.1 Collection and Preparation of Soil Samples

A total 36 soils samples (0-15 cm) were collected in the field through random sampling from six representative soil series of Ganges Meander Floodplain and Ganges Tidal floodplain under different cropping pattern (Boro, T. Aman, Bean, Vegetables, Mustard, Jute, Transplanted Aman and Fallow land etc). Polythene bags were used to collect soil samples from the field. Then the soils were air dried and crushed with a wooden hammer. After crushing the samples were sieved by using 2 mm sieve to separate the coarse (>2 mm) and fine (<2 mm) fractions. The sieved soils were then preserved in plastic container and labelled properly. These were later used for chemical and physical analyses. General information of sampling sites is presented in Table 1.

2.2 Laboratory Analyses

Various chemical and physical analyses were done which are interrelated with each other and essential to correlate the required parameters.

2.2.1 Physical analyses

The particle size analysis of the soils was done by combination of sieving and hydrometer method as described by Gee and Bauder [8]. Textural classes were determined using Marshall's Triangular Coordinates.

Table 1. General information about sampling sites (Ganges meander floodplain and Ganges tidal floodplain soils)

Sample site	Address	Soil series	Cropping Pattern
1	Village: Shabati Union: Ramnagar Thana: Jessore Sadar District: Jessore	Sara	Boro-Fallow-T. Aman
2	Village: Gaithghat Union: Bandabilla Upazila: Bagherpara District: Jessore	Amjhupi	Bean-Fallow-T. Aman
3	Village:Bahadurpur Union: Noapara Thana: Jessore Sadar District: Jessore	Ishurdi	Vegetables/Mustard-Fallow-T. Aman
4	Village: Barakpur Union: Barakpur Thana: Dighalia District: Khulna	Gopalpur	Boro-Jute-T. Aman
5	Vill: Bajoa Union: Dacope Thana: Dacope District: Khulna	Bajoa	Tansplanted aman-fallow
6	Vill: Baranpara, Union: Baitaghata. Thana: Batiaghata District: Khulna	Barisal	Transplanted aman-fallow

2.2.2 Chemical analyses

Soil pH was determined electrochemically with the help of glass electrode pH meter maintaining the ratio of soil to water was 1: 2.5 as suggested by Jackson [9]. The electrical conductivity of the soil was measured at a soil: water ratio of 1: 5 by the help of EC meter [10]. Total nitrogen of the soils was determined by colorimetric method [11] following H_2SO_4 acid digestion as suggested by Jackson [12]. Organic carbon of samples was determined by Walkley and Black's wet oxidation method as outlined by Jackson [9]. Organic matter was calculated by multiplying the percent value of organic carbon with the conventional Van-Bemmelene's factor of 1.724 [13].

2.2.3 Particulate organic matter

The particulate organic carbon was determined by the method of physical fractionation as described by Camberdella and Elliot [14]. Twenty-five g of air-dried soil was dispersed with 100 ml of 5 g/L of sodium hexametaphosphate. Then the solution was shaken for one hour at high speed and poured over a 0.05 mm sieve with several distilled water rinses. The soil remaining on the sieve was washed into a pre-weighted aluminum dish then dried at 60°C for 24-hour, ground and analysed for C. The particulate organic carbon of the soil samples was determined by Tyrin's method as outlined by Kononova [15].

2.2.4 Microaggregate associated carbon

Aggregate size distribution was determined using wet sieving with screen diameters of 0.25 and 0.50 mm [14]. The range of micro-aggregates is between 0.25 to 0.50 mm, respectively. Soil was submerged on the largest screen for five minutes before sieving. Then soil was sieved under water by gently moving the sieve 3 cm vertically 50 times over period of 2 minute through water contained in a shallow pan. Material remained on the sieve was transferred to an aluminum container and dried at 60°C in oven and measured for carbon.

2.3 Statistical Analysis

Data were processed and arranged by Microsoft Excel (version 2013) and Descriptive statistics was calculated by using SPSS software [16].

3. RESULTS AND DISCUSSION

It presents the Isolation and characterisation of particulate organic matter in some soils of Ganges meander floodplain and Ganges tidal floodplain including soil physical and chemical properties. The soil physical and chemical properties are shown in the Tables 2 and 3.

3.1 Particle Size Analysis

Textural class of the soil was found Silty clay loam, Clay, Silty clay, Clay loam and Silt loam at Sara, Ishurdi and Amjhupi, Goplapur, Barisal and Bajoa soil series respectly. The highest value of percentage of sand determined was 23.55% while the lowest percentage was 4.34% found in Barisl and Amjhupi soil series respectively (Table 2). The average value determined was 14.14 (Appendix I). The highest value of percentage of silt determined was 58.79% while the lowest value was 23.27% found in Bajoa and Amjhupu soil series respectively (Table 2). The average value determined was 42.60 (Appendix I). The highest value of percentage of clay determined was 72.39% while the lowest value was 20.33% found in Amjhupi and Bajoa soil series respectively (Table 2). The average value determined was 43.26 (Appendix I).

3.2 Soil pH

The pH of the Ganges Meander Floodplain soils ranges from 6.5 to 7.87 (Table 2) which indicate that the soils are neutral to mildly alkaline and the pH of the Ganges Tidal Floodplain soils ranges from 7.77 to 7.97 (Table 2) which also indicate the same. The highest pH value was 8.01 in soils of Bajoa series located at Dacope in khulna which is moderately alkaline and the lowest was 6.5 in soils of Gopalpur series located at Dighalia in Khulna which is neutral. The other soils remain moderately alkaline range. This might be due to the presence of exchangeable bases within Ganges sediments in the surface soil.

3.3 Electrical Conductivity

In the soil, the Electrical Conductivity reading shows the level of ability the soil water has to carry an electrical current. The values of EC of the soils under study varied from 0.82 to 2.91 dS/m with an average of 1.5 dS/m (Table 2). The showed results indicated that all the studied soils were non-saline. This may be due to the land type of our investigated areas which were out of tidal ingression or any other sort of inputs of salts. Barisal series showed the highest EC value which is developed in Batiaghata, Khulna (Table 2) and the lowest EC value was contained by Amjhupi series in Bagherpara, Jessore (Table 2).

Table 2. Some physical and chemical properties of Ganges Meander floodplain and Ganges tidal floodplain

Soil series	Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC (dS/m)
Sara	13.09	58.79	28.12	Silty clay loam	7.87	0.92
Ishurdi	11.64	25.99	62.37	Clay	7.74	1.03
Amjhupi	4.34	23.27	72.39	Clay	7.72	0.82
Gopalpur	10.99	48.32	40.69	Silty clay	6.5	1.86
Barisal	23.55	40.77	35.68	Clay loam	7.97	4.25
Bajoa	21.24	58.43	20.33	Silt loam	7.77	2.91

Table 3. Different carbon forms and total nitrogen content in soils of Ganges Meander floodplain and Ganges tidal floodplain

Soil series	SOM (g/kg)	POM (g/kg)	SOC 1 (g/kg)	SOC 2 (g/kg)	TN (g/kg)
Sara	11.04	2.90	2.11	7.37	7.37
Ishurdi	16.97	4.84	5.34	7.02	7.02
Amjhupi	13.67	11.62	9.41	10.88	10.78
Gopalpur	17.3	8.11	6.04	9.90	9.90
Barisal	23.56	13.70	11.26	8.78	10.88
Bajoa	16.97	9.80	11.01	8.07	10.25

3.4 Organic Matter

Organic matter status of Bangladesh soil is one of the lowest in the world. The average OM content of Bangladesh soils is less than 1%, ranging between 0.05 and 0.9% in most cases. Soils of peat lands and some low-lying areas usually contain OM higher than 2% on an average. Organic matter content was found highest (23.56 g/kg) in Barisal series and lowest (11.04 g/kg) in Sara series. Organic matter content of other soil series shows that Table 3. Rahman [17] reported that organic matter content from 0.3 to 1.5% in upland soils, 1.5 to 2.0% in the medium low land areas and 2.0 to 3.5% in the low land areas in bill areas, this fraction was about 4%. Cook [18] reported that fine textured soils contain roughly twice as much total organic matter as do sandy soils in the same region. The highest amount of organic carbon was found in Ganges Tidal Floodplain soil while the lowest amount was found in Ganges Meander Floodplain soil.

3.5 Particulate Organic Matter

The active fraction of soil organic matter as well as particulate organic matter was found highest (11.62 g/kg) in Barisal and lowest (2.90 g/kg) in Sara soil series. The particulate organic matter of other soils is given in Table 3. There is a note point that particulate organic matter did not correlate positively with soil organic carbon. Soil of Sara series had lower organic carbon than Ishurdi but higher particulate organic carbon than it. Although the highest amount of POM was found in Ganges meander floodplain soil but the Ganges tidal floodplain soil contain comparatively higher POM than almost Ganges meander floodplain soil.

3.6 Total Nitrogen Content

Because of low level of organic matter, the nitrogen status of Bangladesh soils is substantially low and most crops on all soils respond to nitrogen applications. The highest amount of total nitrogen was found in the soil of Barisal, Amjhupi and Bajoa (10.88 g/kg, 10.78 g/kg and 10.25 g/kg) soil series respectively and the lowest was in Ishurdi (7.02 g/kg) soil series. The total nitrogen content of other soil series is given in Table 3. Total nitrogen content can be correlated with an active fraction of organic carbon as well as particulate organic carbon. We found a positive relation between total nitrogen content and particulate organic carbon. Like POM, the nitrogen content of GTF soil was comparatively higher than almost GMF soils while the highest amount of soil nitrogen was found in GMF soil. The amount of total nitrogen content and particulate organic matter of other soil series is given in Fig. 1.

3.7 Micro-Aggregate Associated Carbon

Aggregates are the smallest unit of soil containing various soil particles. When the soil aggregates are classified according to a range then it can be termed as micro or macro-aggregates. 0.25 mm and 0.50 mm sieves were used to separate micro-aggregate associated carbon. The highest amount of micro-aggregate associated carbon at > 0.50 mm range was found in the soil of Barisal series (11.26 g/kg) and the lowest was in Sara series (2.11 g/kg). The highest amount of micro-aggregate associated carbon in the range of 0.50-0.25 mm was found in Amjhupi series (10.88 g/kg) and the lowest was in Ishurdi series (7.02 g/kg). The amount of micro-aggregate associated carbon of other series is given in Fig. 2.

3.8 Correlation of Different Parameters of Studied Soil

Total nitrogen content of the soils was positively correlated with POM, SOM, clay, pH but negatively correlated with silt. The correlation value between finer particles as well as clay particles and soil organic matter is 0.169 and the P value is 0.749. The correlation value between clay particle and particulate organic matter is 0.076 and the P value is 0.886. But silt and particulate organic matter is negatively correlated. Soil organic carbon associated with the aggregates of 0.50-0.25 mm size range had positive correlation with SOM associated with the

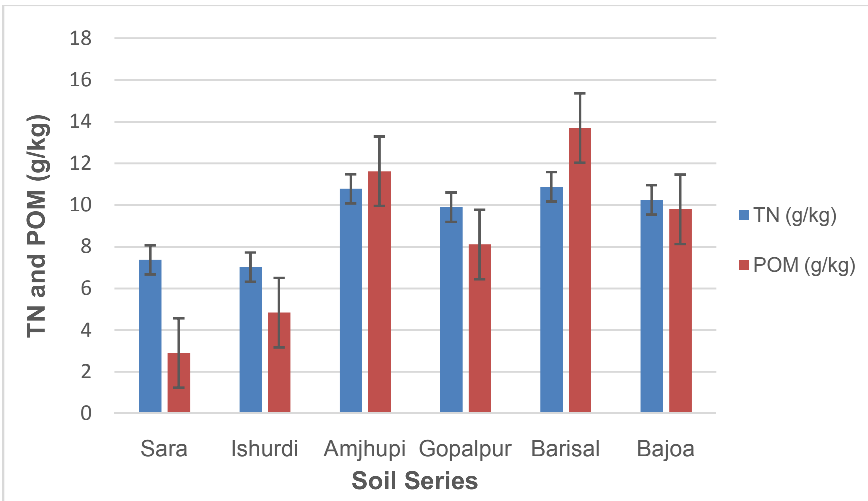

Fig. 1. Total nitrogen and particulate organic matter for different soil series

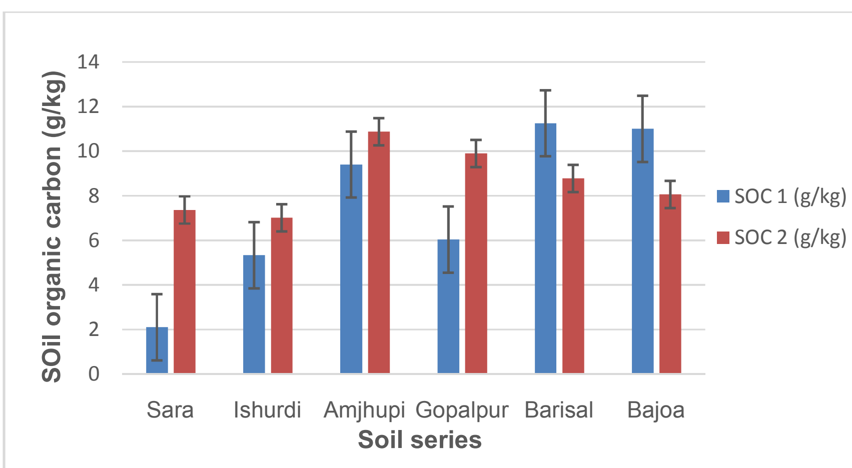

Fig. 2. Microaggregate associated carbon for different soil series

Where, SOC 1: Microaggregate associated carbon (> 0.50 mm)
SOC 2: Microaggregate associated carbon (0.50-0.25 mm)

Table 4. Correlation among selected soil properties

Parameters	SOM	POM	Silt	Clay	pH	TN	C:N	SOC 1
POM	0.894							
	0.016							
Silt	-0.339	-0.202						
	0.511	0.701						
Clay	0.169	0.076	-0.954					
	0.749	0.886	0.003					
pH	0.075	0.140	0.152	-0.316				
	0.887	0.791	0.774	0.542				
TN	0.654	0.429	-0.613	0.376	0.011			
	0.159	0.396	0.196	0.463	0.983			
C:N	0.397	0.585	0.175	-0.084	0.126	-0.412		
	0.436	0.223	0.740	0.874	0.812	0.417		
SOC 1	0.894	0.966	-0.428	0.281	0.140	0.586	0.435	
	0.016	0.002	0.397	0.589	0.791	0.222	0.388	
SOC 2	0.892	0.955	-0.062	-0.021	0.007	0.295	0.696	0.867
	0.017	0.003	0.907	0.969	0.989	0.570	0.124	0.026

Cell Contents: Pearson correlation P-Value
SOC1: Microaggregate associated carbon (>0.50 mm),
SOC 2: Microaggregate associated carbon (0.50-0.25 mm)

aggregates of > 0.50 mm size range. The correlation value (r) between POM and SOM is 0.894 and the P value is 0.016 which is significant at 5% level. The r value between clay and silt is -0.954 and the P value is 0.003 which is highly significant at 5% level. Similarly, the P value between SOC 1 and SOM is significant. The P value between SOC 1 and POM is highly significant. The P value between SOC 2 and SOM is significant while in case of POM it is highly significant at 5% level of significance.

The total SOM increased as clay content increased (Table 4). Similar observations were made by Oades [19] and Hassink [20] and were attributed to the formation of organo-mineral complexes between clay and organic particles with strong bonds [2]. The percentage of SOC associated with 2-0.25 mm and 0.25-0.05 mm aggregates increased with increasing clay percentages of soils. Wiseman and Puttmann [21] described the importance of specific surface of clays rather than percentage of clays in SOC sorption. In the present study, no significant relationship was found between soil organic matter and particulate organic matter. Moreover, previous studies on the effects of soil texture and mineralogy on POM are inconclusive. For example, Needelman et al. [22] and Kolbl and Kogel-Knabner [23] reported increases in POM with an increase in soil clay content but Plante et al. [24] and Hassink [20] did not find any relationship between soil texture and POM. We also found positive relationship between particulate organic matter and total soil nitrogen as nitrogen content increases with increasing particulate organic matter. We also found that silt percentage has negatively correlated with microaggregate associated carbon. The labile organic material may be physically protected from decomposition by its incorporation into soil aggregates [25]. Soil OM can be: (1) physically stabilised, or protected from decomposition, through micro aggregation, or (2) intimate association with silt and clay particles, and (3) can be biochemically stabilised through the formation of recalcitrant SOM compounds.

4. CONCLUSION

Organic matter is considered as the quality indicator of the soil. But it's all parts are not active which can be readily available for plants and microorganisms. For this reason, sometimes there exists lower productivity instead of the presence of organic matter. This is due to the absence of proper amount of active fraction of organic matter as well as particulate organic matter. The presence of particulate organic matter is positively correlated with finer particles as well as clay particles of the soil. We found this positive correlation among most of the studied soil. Total nitrogen content had also a positive relationship with particulate organic matter and clay particles. Carbon contents were associated with aggregates of soil. The microaggregate associated carbon was positively correlated with total nitrogen content. From the analyses of the properties of the studied soil we have found a positive relationship among active fraction of organic matter as well as particulate organic matter, finer particles as well as clay particles and total nitrogen content of the soil.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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APPENDIX

Appendix I. Descriptive statistics of the studied soils

Variable	Mean	Median	Standard deviation	Minimum	Maximum
EC (dS/m)	1.39	1.23	0.58	0.82	2.28
pH	7.76	7.81	0.287	7.22	8.01
% Sand	14.14	12.37	7.10	4.34	23.55
% Silt	42.60	44.55	15.48	23.27	58.79
% Clay	43.26	38.19	20.16	20.33	72.39
SOM (g/kg)	17.16	17.14	4.50	11.04	23.56
POM (g/kg)	8.29	9.56	3.70	2.90	11.620
Total N (g/kg)	1.30	1.28	0.33	0.79	1.73
C:N ratio	7.97	8.01	0.999	6.23	9.26
SOC 1 (g/kg)	6.63	7.06	2.72	2.11	9.41
SOC 2 (g/kg)	9.38	10.08	1.74	7.02	10.88

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