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Effect of rice straw on chemical properties and heavy metals residues in the bottom sediment of fish ponds

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Abstract

This study was conducted to determine the effect of rice straw on some chemical properties and heavy metals accumulation of fish pond bottom sediment in earthen fish ponds. The present work had been conducted in the world fish center during the period from May to December 2017 in six earthen fish ponds having equal areas (1000 m^2) and 1 m water depth All ponds cultured with mono six Nile tilapia fry in the rate of 3 fingerling/ m^2. All ponds were fertilized with dry chicken manure in the rate of 15 kg/pond/week, and divided into two treatments, each of 3 replicates; the first one (T1), act as control, while the second (T2) received 45 kg dry rice straw/pond. Samples were collected at the beggining and at the end of the experiment; from both treatments as well as from the source of water. The study showed that the sediment pH lied in the alkaline side and negatively correlated with organic matter contents. Concentrations of organic matter and organic carbon were significantly higher in T2 than T1, indicating that rice straw increased total carbon in the bottom sediment. Total nitrogen and total phosphorus (TP) concentrations were varied significantly among treatments. The highest value had been recorded in T2. The different investigated parameters were significantly increased at the end of experiment compared to the beggining, expect for C/N and N/P ratios which decreased at the end of the experiment. Concerning the investigated heavy metals; their concentrations had the, following order: Fe > Zn > Cu > Pb > Cd and tended to be higher in the source water then in T1, while the lowest concentrations had been observed in T2. It's observed that the metals concentrations were significantly decreased at the end of experiment compared to the beginning expect for Cd which increased at the end of experiment. The results of this investigation indicated that rice straw improved sediment

characteristics, increased nitrogen availability and decreased the investigated heavy metals residues.

Key words: Chemical properties, heavy metals, bottom sediment, rice straw.

INTRODUCTION

Pond sediment plays a vital role in it's dynamics through interactions with the water. Properties of the pond bottom sediments, processes occurring at and sediment-water interface are very important regarding the well being and growth of fish in ponds. Nutrients and organic residues tend to accumulate at the bottom and are removed from the water phase to some extent. However, an excessive accumulation beyond what could be defined as the carrying capacity of the sediments may result in the deterioration of the pond environment. Sediment contamination with heavy metals has become a global concern because of its adverse effects on ecosystem health and food security, the mobility and bioavailability of heavy metals in soils and bottom sediments strongly depend on their specific chemical and mineralogical forms and their binding characteristics **(Baeyens *et al.,* 2003).** The uses of agricultural by-products have been widely investigated as an efficient alternative for current costly methods of removing heavy metals (**Al Nagaawy and Shalaby, 2014**). Rice straw can reduce the bioavailability of heavy metals in contaminated sediment and reduce their risk of entering the food chain **(Kouping *et al.,* 2014).** It is one of the most important food crops globally, with more than half of the world population fed with rice **(Seck *et al.,* 2012).** Global rice production is projected to increase from 473 million tons in 1990 to at least 781 million tons by 2020 **(International Rice Research Institute, 1989).** Straw is an economical and important source of organic matter and nutrients **(Wang *et al.,* 2011).** Rice straw decomposition releases N, P, and potassium **(Sonnleitner, *et al.,* 2003)**. The application of straw can also increase soil carbon (C) storage **(Bhattacharyya *et al.,* 2012).** Microbial organisms that decompose the straw can act as a nitrogen sink (immobilization) However, the immobilization is temporary. A few weeks to months later, decomposing microbial organisms will act as a nutrient source **(Witt *et al.* 2000).** This study was conducted to throw light on chemical properties and heavy metal contamination in the sediment after the application of rice straw in the earthen ponds.

MATERIALS and METHODS

Sampling:

This study was conducted in six earthen ponds (1000 m^2 surface area and 1 meter water depth) belongs to the world fish center during the period from May to December 2017. The ponds received fresh water from El-Ismailia canal which occasionally mixed with well water and cultured with mono six Nile tilapia fry in the rate of 3 fingerling/ m^2. All ponds were fertilized with dry

chicken manure in the rate of 15 kg/pond/week, which divided into two treatments, each of 3 replicates; the first one (T1), representing the control, while the second (T2) received 45 kg dry rice straw/pond throughout breeding season. Rice straw was in the form of bundles; which suspended from vertical pillars which established along the pond sides. Surficial sediments were collected at the beginning and at the end of the experiment, from both treatments as well as from the source using Ekman grab sampler and stored in pre-cleaned aluminum containers until analysis. sediments samples were air dried and subjected to grain size analysis.

Sediment analysis

Sediment pH was measured with a glass electrode of a digital pH meter (Model 25, Fisher Scientific) inserted into a 1:1 mixture of dry, pulverized sediment and distilled water. Organic matter was measured as loss on ignition at 550°C for 3 hours **(Page *et al.,* 1982)**, while organic carbon (OC %) was calculated from organic matter (OM) data using the conventional conversion: OM=1.72×OC **(Boyd, 1995).**

Total phosphorus (TP) was measured using the dry ash method **(Tavares and Boyd, 2003)** for digestion then phosphorus was colorimetrically estimated using the vanado-molybdate method **(A.P.H.A. 1985).** Total nitrogen content was estimated by using Kjeldalh method **(A.O.A.C. 1990).** Metals in sediment samples were extracted with HNO_3 & HCl acids and H_2O_2 according to **(E.P.A. 1996).** Atomic Absorption Spectrophotometer (Model Thermo Electron Corporation with Gravities furnace, UK) was used to detect the heavy metals concentrations as mg/kg dry weight.

Statistical analysis

Two-way ANOVA was used for chemical parameters in order to compare different treatment and experiment period, and their interactions. Duncan's multiple range tests were performed to compare the significance of means. Differences were considered significant at $p \leq 0.05$. Statistical analyses were made using SPSS for windows version 10 (SPSS, Richmond) as described by **(Dytham, 1999).**

RESULTS and DISCUSSION

Tow-way ANOVA (Table 1) indicated that the investigated application had been affected some chemical properties of sediment such as pH, OM, OC, TC, TN, TP, TC/TN and TN/TP ratio. The decrease of pH values in T2 than that of T1 and source sediment was attributed to high organic content in pond sediments, which resulted from rice straw decomposition **(Van Asten et al., 2005).** The optimum pH range for aquaculture pond sediments is 7.5-8.0 because microbial activity is higher at this pH range **(Boyd and Pipoppinyo, 1994).**

Values of organic matter and organic carbon were significantly higher in T2 than T1. Organic matter percentage ranged from 7.42 to 7.69 % respectively. The same trend was observed also in organic carbon (4.31 to 4.47 %) where it's values in T2 were significantly ($p< 0.05$) higher than those values in T1. Lower concentrations of OC are unsuitable for the growth of benthic organisms which are important food for many aquatic species, while higher OC concentrations lead to anaerobic conditions at the sediment-water interface. In terms of their relationship to aquaculture **Boyd *et al*. (2002)** mentioned that sediment with 3.1 to 15 % organic carbon considered has high organic matter content. Total carbon ranged from 5.92 to 6.12% in T1 and T2 respectively, while the lowest concentration was found in the source sediment. similarly **Saothongnoi *et al*. (2014)** mentioned that the rice straw increased total carbon in soil.

Total nitrogen (TN) and total phosphorus (TP) concentrations were differing significantly ($P<0.05$) among treatments where the highest values had been recorded in T2 compared to T1 and source. TN percentages ranged from (0.41 to 0.44%) in T1 and T2 respectively, while the lowest value was in the source (0.36%). T2 sediments had much higher TP values (0.131%) than T1 (0.095%). The fact that rice straw decomposition releases N, P, and K, may be the reason behind these observations **(Sonnleitner *et al.,* 2003).**

The C/N ratio of organic matter has been widely used as index of the rate at which organic matter will decompose. A low C/N ratio favors more rapid and complete decomposition of sediment organic matter than does for a high C/N ratio **(Boyd *et al,* 1999)**. In the present study, the highest C/N ratios were recorded in T1 (14.44%), while the lowest ones were recorded in T2 (13.91%), the lower C/N ratio may be due to that addition of rice straw increased nitrogen availability is likely due to N mineralized from the straw and increased nitrogen mineralized from soil organic matter **(Van Asten *et al.,* 2005)**. The most favorable C/N ratio for fish production is 10:1 to 20:1 (**Boyd, 1995)**. C/N ratios in the present study in both treatments were within the favorable range for fish production.

In this study, the highest and lowest N/P ratios were recorded in the source and T2 (8.18 and 3.36%) respectively. The low N/P ratio suggests a pattern of increasing nitrogen availability from sediment or may be the organic fertilizer led to increase nitrogen concentration, revealing that straw application improved N availability. The improved N availability was attributed to N mineralized from the straw, and from increased mineralization of soil organic matter **(Weiqi *et al.,* 2017).** Rice straw application improved nitrogen availability through a reduction of volatilization losses as a result of a drop in surface water pH. **(Glissmann and Conrad, 2000).** The efficacy of fertilizers and manures for improving natural productivity mainly depends on the N: P and

C: N ratios in the pond sediment. N:P ratios of 2:1 to 4:1 are desirable for sustained primary productivity of pond water (**Boyd, 1995)**.

As shown in Table (2) most of sediment parameters were increased at the end of the experiment except for pH, TC/TN and TN/TP ratios. Average of organic matter ranged between7.30 and 7.54% in T1, and between 7.45 and 7.92% in T2. Organic carbon ranged between 4.24 and 4.38% in T1, and from 4.33 to 4.60% in T2. While Total carbon ranged between 5.89 and 5.99% in T1, and between 5.93 and 6.30% in T2. Total nitrogen ranged between 0.38 and 0.43% in T1, and between 0.41 and 0.47 in T2. Total phosphorus values were between 0.048 and 0.143 in T1, and between 0.099 and 0.162% in T2 at the beginning and at the end of the study, respectively. TC/TN ratio were between 13.93 and15.39 % in T1, and were between 13.40 and 14.46 % in T2. A TN/TP ratio was between 3.01 and 7.91 % in T1, and were between 2.90 and 4.14 % in T2 at the end and at the beginning of the study.

Tow-way ANOVA (Table 3) indicated that different treatments and experimental period had effect on some metals residues in sediment such as Zn, Cu, Pb and Cd.; except Fe residues which didn't affected neither with treatments nor with experimental period. The investigated metals residues in sediments were found in the following order: Fe > Zn > Cu > Pb > Cd and tended to be higher in sediment from the source and then in T1 while the lowest concentration were in T2. This may be due to that metal ions can be incorporated into food chains and concentrated in aquatic organisms and the fish are the often at the top of aquatic chain and may accumulate large amount of heavy metals from the water **(Agah *etal.*, 2009).**

As shown in Table (4), heavy metals residues in the investigated sediment were decreased at the end of the study except for cadmium which increased at the end of the study comparing with the beginning , and this may be due to that rice straw contains high concentration of cadmium **(Weichang *et al.*, 2012)** and due to the increasing rate of rice straw decomposition, the cadmium well increased in sediment at the end of the study . Fe, Zn, Cu, Cd and Pb residues in the sediment from source site were 134.843, 252.410, 155.077, 1.356, and 6.098 respectively in the source of water. Average Fe residues ranged from 32.602 to 40.358 g/kg in T1, and from 31.119 to 34.603 g/kg in T2. Zn residues were between 73.98 and 88.23 in T1, and were between 71.58 and 84.52 in T2. Cu residues ranged from 44.11 to 53.58 mg/kg in T1, and from 39.55 to 47.07 mg/kg in T2. Pb residues ranged from 1.66 to 4.03 mg/kg in T1, and from 1.58 to 3.62 mg/kg dry weight in T2 at the end and at the beginning of the study, respectively. Cd residues ranged from 1.09 to 2.23 mg/kg in T1 and from 1.43 to 2.54 mg/kg in T2 at the beginning and at the end of the study.

Table 1: Two-Way ANOVA and main effect of treatment and period on chemical properties of the investigated sediments.

Item		**PH**	**OM**	**OC**	**TC**	**TN**	**TP**	**TC/TN**	**TN/TP**
Sign.		Ns	**	Ns		*	**	**	**
Source of variation	Treatment	Ns	Ns	*	**	**	**	**	**
	Period	Ns	*	*	*	*	**	**	**
	Treatment and period	Ns	*	Ns	*	*	**	**	**
Treatment	Source	7.68a	7.32b	4. 25b	5.18c	0.36c	0.044c	14.38a	8.18a
	T1	7.63a	7.42ab	4.31ab	5.92b	0.41b	0.095b	14.44a	4.32b
	T2	7.59b	7.69a	4.47a	6.12a	0.44a	0.131a	13.91b	3.36c
period									
At the beginning		7.69a	7.36b	4.27b	5.65b	0.38b	0.063b	14.74a	6.74a
At the end		7.58b	7.59a	4.41a	5.82a	0.42a	0.116a	13.90b	4.70b

Sign. = significance level * = significant ($P \leq 0.05$), ** = highly significant ($P \leq 0.01$), and ns = not significant.

Table 2: Mean ± SE of some chemical properties of sediment in different treatments at the beginning and at the end of the study.

parameter	source	T1		T2	
		Before	after	before	after
PH	7.68±0.06	7.71±0.09	7.55±0.26	7.66±0.07	7.51±0.23
OM %	7.32±0.03	7.30±0.03	7.54±0.13	7.45±0.01	7.92±0.23
OC %	4.25±0.06	4.24±0.02	4.38±0.07	4.33±0.01	4.60±0.13
TC %	5.18±0.16	5.85±0.13	5.99±0.12	5.93±0.12	6.30±0.22
TN %	0.36±0.005	0.38±0.005	0.43±0.008	0.41±0.007	0.47±0.01
TP %	0.044±0.001	0.048±0.003	0.143±0.004	0.099±0.002	0.162±0.006
TC/TN ratio	14.38±0.14	15.39±0.54	13.93±0.28	14.46±0.60	13.40±0.71
TN/TP ratio	8.18±0.15	7.91±0.32	3.01±0.06	4.14±0.41	2.90±0.12

SE = standard error

Table 3: Two-Way ANOVA and main effect of treatments and period on heavy metals residues in sediment (mg/kg).

Item		**Fe (g/kg)**	**Zn (mg/kg)**	**Cu (mg/kg)**	**Pb (mg/kg)**	**Cd (mg/kg)**
Sign		ns	*	ns	ns	**
Source of variation	Treatment	ns	**	**	**	**
	Period	ns	**	*	**	*
	Treatment and period	ns	**	*	**	*
Treatment	Source	134.843a	252.410a	155.077a	6.098a	1.356b
	T1	36.48b	81.105b	48.845b	2.845b	1.662ab
	T2	32.862b	78.053c	43.314b	2.600b	1.989a
Period	At the beginning	69.935a	141.724a	85.240a	4.585a	1.294b
	At the end	66.188a	132.656b	79.576b	3.114b	2.043a

Sign. = significance level * = significant ($P \leq 0.05$), ** = highly significant ($P \leq 0.01$), and ns = not significant

Table 4: Mean ± SE of the investigated heavy metals residues in sediments of different treatments at the beginning and at the end of the study.

parameter	source	T1		T2	
		Before	after	before	after
Fe (g/kg)	134.843 ±2.503	40.358 ±2.723	32.602 ±3.865	34.603 ±3.274	31.119 ±3.813
Zn (mg/kg)	252.41 ±5.60	88.23 ±4.89	73.98 ±3.13	84.52 ±23.90	71.58 ±31.53
Cu (mg/kg)	155.07 ±5.50	53.58 ±2.25	44.11 ±5.97	47.07 ±11.29	39.55 ±3.62
Pb (mg/kg)	6.09 ±0.37	4.03 ±0.18	1.66 ±0.71	3.62 ±0.42	1.58 ±0.68
Cd (mg/kg)	1.35 ±0.04	1.09 ±0.03	2.23 ±0.62	1.43 ±0.01	2.54 ±0.05

CONCLUSION

From the results of the present investigation, it could be concluded that the use of rice straw in earthen fish ponds to improved chemical properties of sediment and increased nitrogen availability for the fish, and decreased heavy metals residues in the sediment.

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تأثير قش الأرز علي الخواص الكيمائية وتراكم العناصر الثقيلة في راسب قاع الأحواض السمكية

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الملخص العربي

نظرا لانتشار استخدام قش الأرز كمحسن لخواص جودة المياه في الفترة الاخيرة لذا أجريت هذه الدراسة لتقييم الاثر علي خواص التربة الكيميائية وتراكم العناصر الثقيلة بها. وتم استخدام ستة احواض ترابية, تبلغ مساحة كل منها حوالي ١٠٠٠م^{٢} وعمق المياه بها حوالي ١م , تم استزراع الاحواض بإصبعيات البلطي النيلي وحيد الجنس بمعدل ٣ اصبعيات/ م^{٣} وتم تسميد كل الأحواض بزرق الدواجن بمعدل ١٥ كجم/ حوض / اسبوعيا. وقد قسمت هذه الاحواض الي مجموعتان كل مجموعة بثلاث مكررات. احداهما مجموعة ضابطة لم يتم اضافة قش الارز اليها (كنترول). والاخري تم وضع قش الارز بمعدل ٤٥كجم/ حوض طوال فتره التجربه. واستمرت فترة التجربة طوال موسم الاستزراع بداية من شهر مايو وحتي شهر ديسمبر ٢٠١٧وتم اخذ عينات من التربة في بداية التجربة وفي نهايتها وايضا تم اخذ عينات من مصدر المياه. وأظهرت النتائج أن نسبة تركيز المواد العضوية تتناسب عكسيا مع تركيز ايون الهيدروجين, وانه توجد فروق ذات دلالة إحصائية في تركيز المواد العضوية والكربون العضوي بين المعاملتان لصالح المعاملة الثانية واظهرت النتائج أن قش الارز يزيد من نسبة الكربون الكلي. وان هناك فروق ذات دلالة إحصائية في تركيز النتيروجين الكلي والفوسفور الكلي بين المعاملات حيث سجلت المعاملة الثانية أعلي تركيز مقارنة بالمعاملة الاولي والمصدر. وأن كل الخواص الكيميائية المختبرة تزيد في نهاية فترة التجربة ما عدا نسبة الكربون الكلي : النتروجين الكلي ونسبة النيتروجين الكلي: الفوسفور الكلي التي قلت مع نهاية فترة التجربة مقارنة بالبداية. أما فيما يتعلق بتركيز العناصر الثقيلة فقد أظهرت النتائج أن رواسب قاع المصدر سجلت اعلي تركيز بينما كانت المعاملة الثانية اقل تركيزا. واخذت العناصر الترتيب التالي: الحديد > الزنك > النحاس > الرصاص > الكادميوم. وكان هناك فروق ذات دلالة إحصائية بين تركيز العناصر في بداية ونهاية فترة التجربة حيث انخفض تركيز جميع العناصر مع نهاية فترة التجربة ما عدا الكادميوم الذي زاد تركيزه مع نهاية فترة التجربة. وقد اتضح من النتائج السابقة ان قش الارز يمكن استخدامه لتحسين الخواص الكيمائية لرواسب قاع المزارع السمكية حيث انه يزيد من اتاحة النيتروجين للاسماك بالاضافة التي تقليل نسبة العناصر الثقيله بها.