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USABILITY OF BIOSLURRY TO IMPROVE SYSTEM PRODUCTIVITY AND ECONOMIC RETURN UNDER POTATO-RICE CROPPING SYSTEM

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ABSTRACT

Establishment of huge number of biogas plant in the recent years in Bangladesh creates a burden to disposal of bioslurry. An attempt was undertaken to explore the usability of bioslurry in agricultural crop production under potato-rice system as well as to reduce bioslurry induced pollution. The experiment involved a sole chemical fertilizer treatment, four treatments based on integrated plant nutrition system with 5 t ha^{-1} cowdung and cowdung bioslurry and 3 t ha^{-1} poultry manure and poultry manure bioslurry, and a control. The potato crops received manures or slurries, and its residual effect was evaluated on the succeeding T.*Aman* crop. Poultry manure bioslurry, poultry manure, cowdung bioslurry and cowdung gave 22.5, 20.0, 9.9 and 2.9 % increase in total system productivity, respectively over sole chemical fertilizer treatment. Bioslurries had higher contribution compared to their respective original manure. Bioslurry was found very useful as manure for crop production.

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INTRUDUCTION

The Government of Bangladesh has been implementing the National Domestic Biogas and Manure Program (NDBMP) since 2006. Under this program the Infrastructure Development Company Limited (IDCOL), with financial assistance from SNV, Netherlands and KfW Germany, has installed more than 31,000 biogas plants by the year 2013. Bioslurry produced from these biogas digesters is mostly being wastage, polluting the environment many cases and becoming a major burden in Bangladesh (Islam, 2011). This is happening due to less awareness and knowledge gap of the farmers about the nutritional value of bioslurry for crop production. If properly managed, bioslurry could play a major role in supplementing the use of expensive chemical fertilizers in Bangladesh (Yu et al., 2010; Abubaker, 2012).

The farmer needs to use chemical fertilizer to increase the crop production. However, if only chemical fertilizers are continuously applied to the soil without adding organic manure, productivity of land will decline. On the other hand, if only organic manure is added to the soil, desired increase in crop yield cannot be achieved. Some literature is available in Bangladesh on the effects of integrated use of aerobically decomposed manure and chemical fertilizers on various crops. The anaerobically digested manure like use of bioslurry under integrated plant nutrition system is very minimum addressed in the country as well as in the world. The experiment is therefore, undertaken to investigate the usability of bioslurry as manure in the potato-rice cropping system.

MATERIALS AND METHODS

The experiment was carried out during 2011 and 2012 at Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) farm, Mymensingh. The BAU farm soil belongs to 'Sonatala' soil series an Inceptisol under the AEZ 9 (Old Brahmaputra Floodplain).The silty clay loam soil had the following properties at 0–15 cm depth: sand 96 g kg^{-1}, silt 700 g kg^{-1}, clay 204 g kg^{-1}, 6.4 pH, 2.13% organic matter, 1.1 mg g^{-1} total N, 5.00 mg kg^{-1} available P (Olsen), 0.11 cmol kg^{-1} exchangeable K, 12.0 mg kg^{-1} available S, 0.65 mg kg^{-1} available Zn and 0.24 mg kg^{-1} available B contents.

The experiment was laid out in a completely randomized block design with three replications, each plot size being 4 × 5 m and was separated by bunds. There were six treatments, namely recommended rate of nutrients from chemical fertilizers (T_1), and the next four treatments on integrated plant nutrition system (IPNS) basis i.e. recommended rate of nutrients from chemical fertilizer adjusted from manures - cowdung (T_2), cowdung bioslurry (T_3), poultry manure (T_4) and poultry manure bioslurry (T_5). The control treatment (T_6) received no fertilizer or manure. When N, P, K and S were supplied from organic and inorganic sources based on IPNS basis; the amount of all nutrients was equal for all the treatments except T_6. The rate of manure application was 5 t ha^{-1} for cowdung and cowdung bioslurry and 3 t ha^{-1} for poultry manure and poultry manure bioslurry. The treatments were tested on potato-rice cropping system in two consecutive years. In each crop cycle, manure was applied to the first crop (potato) and their residual effect was evaluated on the succeeding T. Aman rice. The nutrient content of the manures are given in Table 1. The rate of fertilizer for potato was 135, 25, 95 and 12 kg ha^{-1} of N, P, K & S, respectively for T_1- T_6.The T. Aman rice received equal amounts of N, P, K & S as chemical fertilizers at a rate of 75, 8, 30, 8 kg ha^{-1}, respectively. A blanket dose of Zn and B @ 2 and 1.5 kg ha^{-1}, respectively were applied in all plots of potato crops. Basal application of P, K, S, Zn and B, and treatment wise manures were made during final land preparation. Nitrogen was top dressed at 3 equal splits on final land preparation, 20 and 40 days after planting for potato and on 10, 25 and 45 days after transplanting for T. Aman rice.

The potato tubers were planted maintaining spacing of 20×50 cm. For T. Aman rice 25 days old 3-4 seedlings comprising a hill were transplanted in rows maintaining 20×20 cm spacing. The potato tubers were planted on 24 and 23 November of 2010 and 2011 and T. Aman rice seedlings were transplanted on 27 and 29 July of 2011 and 2012, respectively. The crop varieties were Diamant for potato and BINA dhan7 for T. Aman rice. Two weeding cum earthing-up followed by irrigation was made in potato whereas T. Aman rice was grown on rain-fed condition. All crop protection measures were taken to prevent insect and disease attacks. Yields of tuber/grain and stover/straw of each crop were recorded after harvest of a 6 m^2 area from each plot at physiological maturity. Observation was made in terms of yield and yield components. Total system productivity was calculated through addition of potato yield and potato equivalent rice yield (PERY).

The PERY was calculated according to the following equation (Ahlawat and Sharma, 1993):

$$PERY = \frac{Y_{rice} \times P_{rice}}{P_{potato}} \quad \text{---------- (1)}$$

Where, Y_{rice} is the yield of rice (t ha^{-1}), P_{rice} is the price of rice (Tk 15000 t^{-1}), $Y_{potato}$is the yield of potato (t ha^{-1}) and P_{potato} is the price of potato (Tk 10000 t^{-1}).

Economic analysis was performed to identify the economically viable treatment(s). Marginal benefit-cost ratio (MBCR) is the indicative of the superior treatments. It is the ratio of marginal or added benefits and costs. Only variable costs i.e. manure and chemical fertilizer was taken into account as added cost. The benefit was calculated based on yield (main product and by-product). Data recorded on crop characters were subjected to statistical analysis through computer based statistical program Mstat-C following the basic principles, as outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Contribution to growth and yield components of potato

Potato stem length, number of tubers plant^{-1}and tuber weight plant^{-1} were significantly influenced by the application of organic manure and inorganic fertilizers (Table 2). Stem length across the treatments ranged from 15.5 - 46.2 cm in 2011 and 21.8 - 52.5 cm in 2012.The tallest plants were found in PM bioslurry + IPNS basis chemical fertilizer (T_5) treatment in 2011. In 2012, the tallest plants were recorded with the T_4 treatment (PM + IPNS basis chemical fertilizer), however, it was statistically similar with T_6 treatment. Table 2 indicates that in both years the highest number of tubers plant^{-1} was recorded by T_5 treatment (6.08 in 2011 and 5.97 in 2012) and it was statistically similar with T_4 treatment (5.93 in 2011 and 5.77 in 2012). Regarding cattle manure sources, in both years higher number of tubers was produced by the T_3 treatment (CD-bioslurry + IPNS basis chemical fertilizer) compared to the original manure (T_2). The number of tubers plant^{-1} produced by the treatment T_1 (chemical fertilizer) was lower in relation to the IPNS treatments. In the first year trial, the highest and the next highest tuber weight plant^{-1} (g) were recorded by the treatments T_5 and T_4, respectively. Unlike first year, the highest tuber weight (302 g plant^{-1}) was produced by the T_4 treatment and it was statistically similar to T_5 treatment (295.8 g plant^{-1}). Treatment T_3 (CD bioslurry + IPNS basis chemical fertilizer) had higher tuber weight plant^{-1} in both years compared to the treatment T_2 (CD + IPNS basis chemical fertilizer).

Results of potato grading (A, B, C and D grade) based on tuber weight (%) are presented in Table 3. As observed in 2011, 27.8 % potato in treatment T_1 belongs to 'D' grade (extra-large size) and in the following year (2012), 14.0 % potato for the same treatment (T_1) fall under 'D' grade. The manure receiving treatments (T_2 to T_5) had 6.4 to 11.3 % 'D' grade potato over the years which were much lower compared to absolutely chemical fertilizer treatment (T_1). The 'C' grade (under size) potato was not much influenced by the treatments. Remarkable variation was observed in 'B' grade potato and was always higher in treatments that received manures (T_2-T_5). When 'A' (seed purpose) and 'B' (consumption purpose) grade potatoes were pooled, it was found that in 2011 about 60-65% potatoes produced by T_1 treatment belonged to these two grades and more than 80% potatoes of the T_2 – T_5 treatments fall in these groups. In 2012, 80% potatoes in T_1, and more than 90% in T_2 – T_5 fell into these groups. The results clearly indicated that integrated nutrient management had a distinct impact to produce the good size/quality of potato.

Contribution to tuber and stover yield of potato

Tuber yield of potato was influenced significantly by the different treatments (Table 4). In 2011, the range of tuber yield over the treatments was recorded as 3.00 to 21.80 t ha^{-1}, which was 5.40 to 25.28 t ha^{-1} in 2012. As recorded in the first year, the highest tuber yield was found in T_5 treatment (PM-bioslurry + IPNS basis chemical fertilizer) and it was statistically similar with the T_4 treatment (PM + IPNS basis chemical fertilizer). In the second year, the highest yield was observed in T_4 treatment and statistically similar yield was noted in T_5 treatment. When the two years' yields were pooled, the range came to 4.20 to 23.44 t ha^{-1}. Both the years,

treatment T_3 (CD bioslurry + IPNS basis chemical fertilizer) showed statistically higher tuber yield than T_2 (CD + IPNS basis chemical fertilizer).Table 4 further indicates that sole chemical fertilizer treatment (T_1) had significantly lower yield compared to the IPNS treatments. The two years' pool data indicate that although not significant but higher stover yield was produced by poultry manure bioslurry than poultry manure. After poultry source, cowdung bioslurry (T_3) ranked the third position in relation to stover yield of potato. Poultry manure source produced the higher yield, as because some growth hormones and concentrates feed to poultry birds increased the growth of plants. Ullah et al. (2008) noted that the treatment where poultry manure bioslurry was used showed higher yield of different crops (tomato, cabbage, cauliflower, potato, maize and Boro rice). Singh (1995) reported that biogas slurry was found better than organic manure (FYM) in obtaining higher yield in pea, okra, corn and soybeans.

Table 1. Chemical composition of different manures used in potato 2011 and 2012

Manure	C(%)	N(%)	P(%)	K(%)	S(%)	C:N	C:P	C:K	C:S
				2011					
Cowdung (CD)	25.1	1.06	0.40	0.48	0.20	23.8	62.6	52.5	125.8
CD bioslurry	23.7	1.14	0.48	0.51	0.24	20.7	48.9	46.5	98.2
Poultry manure (PM)	19.7	1.42	0.81	0.67	0.30	13.9	24.3	29.4	66.1
PM bioslurry	13.9	1.54	1.44	0.58	0.39	9.0	9.65	24.0	35.6
				2012					
Cowdung (CD)	40.7	1.08	0.58	0.54	0.33	37.7	60.0	75.4	123.3
CD bioslurry	32.7	1.55	0.84	0.67	0.35	21.2	38.9	48.5	93.4
Poultry manure (PM)	23.9	1.64	0.95	0.53	0.41	14.6	25.2	45.1	58.3
PM bioslurry	16.8	1.68	1.34	0.64	0.49	10.0	12.5	26.3	34.3

Table 2. Effects of different manure and fertilizer treatments on the growth and yield components of potato (Diamant) in the potato-T. Aman rice cropping system

Treatments	Stem length(cm)		Tuber plant^{-1} (no.)		Tuber wt. plant^{-1} (g)	
	2011	2012	2011	2012	2011	2012
T_1: Chemical Fertilizer (CF)	37.1 c	41.1 b	4.10 c	5.13 a	210.6 cd	236.6 b
T_2: CD+IPNS basis CF	35.5 c	40.4 b	4.10 c	5.30 a	195.3 d	243.5 b
T_3: CD-bioslurry+IPNS basis CF	37.7 c	45.6 b	4.93 b	5.53 a	225.9 c	253.1 b
T_4: PM+IPNS basis CF	43.2 b	52.5 a	5.93 a	5.77 a	324.9 b	302.0 a
T_5: PM-bioslurry+IPNS basis CF	46.2 a	52.2 a	6.08 a	5.97 a	353.8 a	295.8 a
T_6: Control	15.5 d	21.8 c	1.93 d	3.23 b	40.03 e	59.60 c
SE (±)	0.8738	1.9683	0.091	0.2936	4.9330	10.938

Table 3. Effects of different manure and fertilizer treatments on the different grades of potato (%) in the potato-rice cropping system

Treatment	**2011**				**2012**			
	'A' grade	'B' grade	'C' grade	'D' grade	'A ' grade	'B' grade	'C' grade	'D' grade
T_1: Chemical Fertilizer (CF)	22.0	40.3	9.9	27.8	38.6	42.5	4.9	14.0
T_2: CD+IPNS basis CF	34.4	50.4	7.1	8.1	46.8	46.3	6.9	-
T_3: CD-bioslurry+IPNS basis CF	33.5	50.3	7.6	8.6	45.0	52.1	2.9	-
T_4: PM+IPNS basis CF	19.0	62.9	7.7	10.4	30.9	56.3	4.1	8.7
T_5: PM-bioslurry+IPNS basis CF	20.7	65.1	5.7	8.5	39.8	48.0	5.8	6.4
T_6: Control	81.3	-	18.7	-	63.3	-	36.7	-

'A' grade= 28-40 mm diameter, 'B' grade=41-55 mm, 'C' grade= <28 mm, 'D' grade= >55 mm

Table 4. Effects of different manure and fertilizer treatments on the grain and straw yields of potato (Diamant) in the potato-T. Aman rice cropping system

Treatments	Tuber yield (t ha^{-1})			Stover yield (t ha^{-1})		
	2011	2012	Mean	2011	2012	Mean
T_1: Chemical Fertilizer (CF)	16.34 c	20.85 d	18.60 c	0.803cd	0.944 c	0.874 c
T_2: CD+IPNS basis CF	15.91 c	22.48 c	19.19 c	0.746 d	1.010bc	0.878 c
T_3: CD-bioslurry+IPNS basis CF	17.79 b	23.59 b	20.69 b	0.843 bc	1.068 b	0.955 b
T_4: PM+IPNS basis CF	21.04 a	25.28 a	23.16 a	0.920ab	1.327 a	1.124 a
T_5: PM-bioslurry+IPNS basis CF	21.80 a	25.08 a	23.44 a	0.979 a	1.275 a	1.127 a
T_6: Control	3.00 d	5.40 e	4.20 d	0.080 e	0.311 d	0.195 d
SE (±)	0.4344	0.2817	0.3151	0.0242	0.0308	0.0216

Table 5. Residual effects of different manure and fertilizer treatments on yield contributing characters of T. Aman rice (BINA dhan7) in the potato -T. Aman rice cropping system

Treatments	Tillers hill^{-1} (no.)		Grains panicle^{-1} (no.)		1000-grain weight (g)	
	2011	2012	2011	2012	2011	2012
T_1: Chemical Fertilizer (CF)	13.13 a	12.03 b	81.17 a	89.10 b	22.13	22.82
T_2: CD+IPNS basis CF	15.07 a	11.70 b	87.90 a	89.60 b	22.57	21.76
T_3: CD-bioslurry+IPNS basis CF	15.43 a	13.03 a	88.67 a	92.87 ab	22.53	22.73
T_4: PM+IPNS basis CF	15.07 a	12.10 b	90.03 a	96.07 a	23.00	22.71
T_5: PM-bioslurry+IPNS basis CF	15.73 a	13.33 a	91.27 a	96.57 a	22.20	22.81
T_6: Control	9.133 b	7.933 c	67.13 b	74.23 c	21.87	22.04
SE (±)	0.8469	0.2726	3.1819	1.2902	0.2392	0.2907

Table 6. Residual effects of different manure and fertilizer treatments on the grain and straw yields of T. Aman rice (BINA dhan7) in the potato-T. Aman rice cropping system

Treatments	Grain yield (t ha^{-1})			Straw yield (t ha^{-1})		
	2011	2012	Mean	2011	2012	Mean
T_1: Chemical Fertilizer (CF)	4.110 c	4.194 b	4.152 c	4.619 b	4.473 c	4.546 c
T_2: CD+IPNS basis CF	4.223 bc	4.358 ab	4.291 bc	4.807 b	4.621 bc	4.714 bc
T_3: CD-bioslurry+IPNS basis CF	4.397 ab	4.440 ab	4.418 b	4.814 b	4.807 b	4.811 b
T_4: PM+IPNS basis CF	4.367 ab	4.404 ab	4.386 b	4.818 b	4.596 bc	4.707 bc
T_5: PM-bioslurry+IPNS basis CF	4.529 a	4.635 a	4.582 a	5.136 a	5.086 a	5.111 a
T_6: Control	2.728 d	2.633 c	2.680 d	3.036 c	3.155 d	3.096 d
SE (±)	0.0623	0.0838	0.0521	0.0965	0.0776	0.0737

Residual effects on yield components of T. *Aman* rice

In both years, the number of tillers hill^{-1}and grains panicle^{-1}was significantly varied due to fertilizers and manures added to the first crop (Tables 5). In 2011 and 2012, the number of tillers hill^{-1} varied from 9.1 to 15.7, and 7.9 to 13.3, respectively. In both years higher number of tillers hill^{-1} was recorded in T_5 treatment. The number of grains panicle^{-1} varied from 67.1 to 91.3 in 2011 and from 74.2 to 96.6 in 2012, the highest

result being recorded further in treatment T_5.The 1000-grain weight ranged from 21.9-23.0 g in 2011 and from 21.8-22.8 g in 2012 with no statistical difference among the treatments (Table 5).

Table 7. Effects of different manure and fertilizer treatments on the total system productivity and economic return in the potato-T. *Aman* rice cropping system

Treatments	Total system productivity			Economic return			
	2011	2012	Mean	Gross return (Tk ha^{-1})	Added cost (Tk ha^{-1})	Added return (Tk ha^{-1})	MBCR
T_1: Chemical Fertilizer (CF)	22.51 c	27.14 d	24.82 c	255949	20394	168904	8.28
T_2: CD + IPNS basis CF	22.24 c	29.01 c	25.63 c	264193	20995	177148	8.44
T_3: CD-bioslurry+IPNS basis CF	24.39 b	30.25 b	27.32 b	281370	20504	194325	9.48
T_4: PM + IPNS basis CF	27.60 a	31.89 a	29.74 a	305639	21599	218594	10.12
T_5: PM-bioslurry+IPNS basis CF	28.59 a	32.04 a	30.31 a	311892	21433	224847	10.49
T_6: Control	7.093 d	9.347 e	8.223 d	87045	0	0	-
SE (±)	0.3965	0.2888	0.2808	-	-	-	

Price of inputs and outputs: Urea- 20 Tk kg^{-1}, TSP- 25 Tk kg^{-1},MoP- 25 Tk kg^{-1}, Gypsum- 8 Tk kg^{-1},Cowdung and cowdung-slurry- 1 Tk kg^{-1}, Poultry manure and poultry manure slurry- 2 Tk kg^{-1}, Potato tuber- 10 Tk kg^{-1}, Potato haulm- 1Tk kg^{-1}, Rice grain- 15 Tk kg^{-1}, and rice straw- 1.5 Tk kg^{-1}

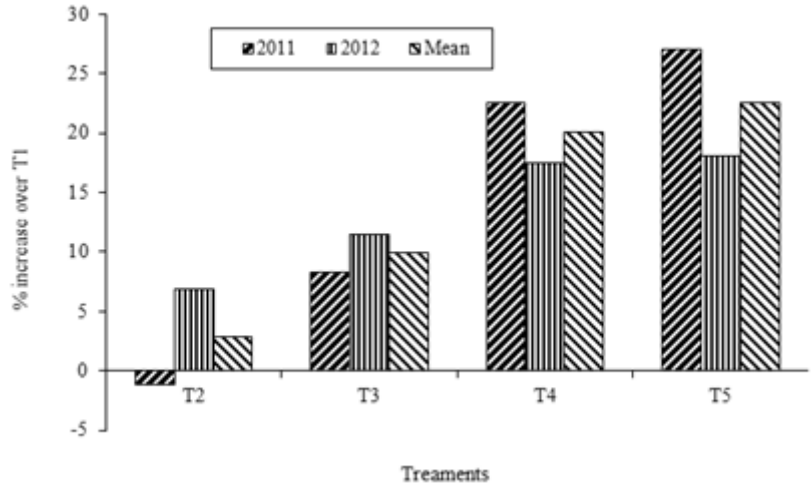

Figure 1. Percent increase of total system productivity by different IPNS treatments over chemical fertilizer treatment (T_1)

Residual effects on grain and straw yield of *T. Aman* rice

Application of manure and fertilizers to the previous potato crop significantly increased the grain and straw yield of *T. Aman* rice (second crop) in both years (Table 6).The grain production by different treatments ranged from 2.73 – 4.53 t ha^{-1} in 2011, and 2.63 – 4.64 t ha^{-1} in 2012. In both years, the highest grain yield was recorded by the T_5 treatment (PM-bioslurry + IPNS basis chemical fertilizer) and the second highest yield by the T_3 treatment (CD-bioslurry + IPNS basis chemical fertilizer). The straw yield ranged from 3.04 t ha^{-1} in T_6 treatment to 5.14 t ha^{-1} in T_5 treatment in 2011 and in 2012 the yield varied from 3.16 t ha^{-1} in T_6 treatment to 5.09 t ha^{-1} in T_5treatment.The two years' mean yield results indicated that the highest straw yield (5.11 t ha^{-1}) and the second highest (4.81 t ha^{-1}) yield were recorded in T_5 and T_3 treatments, respectively. Dwivedi and Thakur (2000) reported that among the organic manures applied to rice crop, biogas slurry and rice straw incorporation resulted in significant residual effect.

Contribution to total system productivity

Total system productivity was significantly influenced by different treatments ranging from 7.09 to 28.59 t ha^{-1} in 2011 and 9.35 to 32.04 t ha^{-1} in 2012 (Table 7). The poled TSP varied from 8.22 to 30.31 t ha^{-1} (Table 7). Both the years highest TSP was found in the treatment T_5 (PM-bioslurry+IPNS with chemical fertilizer) which was in 2012 statistically similar with T_4. Regarding cowdung source cowdung bioslurry had the higher TSP. Table 7 thus indicated that all the IPNS treatment had higher TSP compared to sole chemical fertilizer treatment (T_1) except T_2 in 2011. Among the IPNS treatments, PM-bioslurry, poultry manure, cowdung bioslurry and cowdung had the 22.5%, 20.0%, 9.9% and 2.9%increase in TSP over sole chemical fertilizer treatment (T_1) (Figure 1).Jeptooet al. (2013) reported that application of 7.8 t ha^{-1} of bioslurry increased yields of carrot by 8.8% in season 1 and 23.5% in season-2 compared to the control.

Contribution to economic profitability

It appears from Table 7 that the T_5 treatment had the highest marginal benefit-cost ratio (MBCR) (10.49), which was followed by T_5 treatment (10.12). The highest gross return was also found in T_5 treatment. Other IPNS treatments exhibited higher economic performance compared to sole chemical fertilizer treatment. Higher economic profitability in IPNS treatments was associated with lower market price of manures due to local availability, whereas purchasing chemical fertilizers require much higher money in one way; on the other way higher yield had a positive reflection in economic performance of IPNS treatments. Nevertheless if the benefit of manure use to the improvement of soil properties is added, all the manure based treatments (T_2-T_5) would produce higher benefits over all other treatments. Indeed, for achieving sustainable crop yield without incurring loss to soil fertility, the IPNS approach i.e. combined application of manure and fertilizers deserves attention.

CONCLUSION

Poultry manure bioslurry or cowdung bioslurry gave greater amount of tuber/grain and stover/straw yield compared to their respective original state. Poultry manure source produce significantly greater yield than cowdung.

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