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Heavy Metals Accumulation in Cauliflower (*Brassica Oleracea* L. var. *Botrytis*) Grown in Brewery Sludge Amended Sandy Loam Soil

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Abstract

An experiment was conducted to study the effects of five levels of brewery sludge (BS) (0, 5, 10, 15 and 20 Mg ha^{-1}) and recommended dose of chemical fertilizers (100:60:50 NPK ha^{-1}) on heavy metals content of soil and plant parts (leaf and Curd) of cauliflower. Brewery sludge application significantly increased the heavy metals (Zn, Cu, Pb, Cr and Cd) concentration in both soil and plant parts of cauliflower as compared to the unamended soil. The highest heavy metals concentrations in soil and plant parts (curd and leaf) were recorded from 20 Mg ha^{-1} BS application. Accumulation of heavy metals in leaf was higher than in curd. The curd yield of cauliflower significantly increased with brewery sludge application as compared to control. Heavy metals in soil were within the USEPA permissible limits. Leaf and curd in all treatments assimilated Zn and Cu below the FAO/WHO maximum permissible value. But Pb and Cd concentrations in leaf and curd exceeded the FAO/WHO maximum permissible value, except Pb concentration in curd from control and 5 Mg ha^{-1} BS application. Cr concentration was below the FAO/WHO maximum permissible value in curd; whereas the concentration in leaf surpassed the maximum permissible value except in unamended soil and 5 Mg ha^{-1} BS application. Thus, this study highlights the risk involved in consumption of cauliflower receiving brewery sludge and likelihood of human exposure to heavy metals.

Key words

Brewery Sludge; Heavy Metals; Leaf; Curd

Introduction

Sludge, one of the principal byproducts produced from various wastewater treatment plants (Odegaard, Paulsrud, and Karlsson, 2002), can be used as fertilizer in agricultural lands for the production of agricultural crops. Application of sewage sludge serves numerous functions including macro and micro nutrients supplement to crops, ameliorating the soil physical properties and augmenting the organic matter content in soil; all contributing to an increment in crop production (Mantovi, Baldoni, and Toderi, 2005). However, the sewage sludge application may result in heavy metals accumulation in the soil (Chen, Wang, and Wang, 2005; Arora *et al.*, 2008). As a result, plants may absorb heavy metals above the permitted levels and enter the food chain affecting the human beings health (Arora *et al.*, 2008). Effective management of sewage sludge must overcome such undesirable effects in crop production systems (Skjelhaugen, 1999). Therefore, the proper management of sludge utilization must consider many aspects including its heavy metal content, crop type and its nutrient requirement, and biological and physico-chemical properties of soil. These aspects are essential to determine the optimum rate, time and method of sludge application (Banerjee, Burton, and Depoe, 1997; Arora *et al.*, 2008).

In Nawalparasi, Nepal, brewery industries generate large quantities of solid wastes. Farmers residing in this area exploit solid waste (sludge) for agricultural production. Heavy metals concentrations in soil and plant tissue may increase with the use of sludge for vegetable production posing threats to health of consumers. Hence, this study aims to assess the influence of brewery industry sludge application on soil heavy metals content, yield of cauliflower and heavy metals uptake by leaf and curd.

Materials and Methods

A field experiment was carried out at Divyapuri 5, Nawalparasi, Nepal from October to December 2008 to assess the effects of brewery sludge on heavy metals contents of soils and plant parts of cauliflower (*Brassica oleracea* L. var. *botrytis*). The experiment was laid out in Randomized Complete Block Design with four replications in sandy loam soil. There were six treatment combinations having five rates of brewery sludge (0, 5, 10, 15, 20 Mg ha^{-1}) and the recommended doses of chemical fertilizers (100:60:50 kg NPK ha^{-1}). Cauliflower, a popular vegetable in Nepal, was selected for the experiment. The dewatered brewery sludge (BS) produced from beer factory of Chaudhary Udhyog; Nepal was applied into the plot seven days before transplanting cauliflower seedlings. Nitrogen was supplied through urea in two split application and phosphorous and potash was supplied through Diammonium Phosphate and Muriate of Potash as basal application, respectively.

Soil samples, prior to experiment and after the crop harvest, were collected from each plot. The BS was sampled from the brewery waste water treatment plant. The soil and BS samples were air dried, grinded and passed through a 1mm sieve to analyze their chemical properties. The pH level was determined by the Beckman electrode pH meter in a suspension of soil and water at 1:2.5 ratio (Cottenie *et al.*, 1982), soil and BS organic matter content by using modified Walkley and Black method (Houba *et al.*, 1989), total soil and BS nitrogen by the Kjeldahl distillation method (Bremner and Mulvaney, 1982), available soil Phosphorous by the $NaHCO_3$ extraction method (Olsen, Sommers, and Page, 1982) using spectrophotometer, and available soil Potassium by the ammonium extraction method (Pratt, 1965) using flame photometry. Air dried soil and sludge samples were acid digested using HNO_3 and HCl mixture at 3:1 ratio along with 30% H_2O_2 (Edgell, 1989) and analyzed for total Zn, Cu, Pb, Cr and Cd content. Total sludge K and total sludge P were determined by Atomic absorption Spectrophotometer.

Leaf and curd samples, collected separately from each plot, were oven dried, grinded and passed through 1 mm sieve. Oven dried samples were acid digested with the mixture solution of HNO_3, H_2SO_4 and $HClO_4$ at 5:1:1 ratio (Allen, Grimshaw, and Rowland, 1986). The solution obtained after the filtration of digested sample was analyzed to determine heavy metals (Zn, Cu, Pb, Cr and Cd) by Atomic Absorption Spectrophotometer. Data were subjected to Analysis of Variance using MSTAT-C software and Duncan's Multiple Range Test was performed to separate different treatment means using DMRT at 5% probability level.

Results

Characteristics of Soil and Brewery Sludge

The selected characteristics of soil and brewery sludge were presented in Table 1. The soil and brewery sludge are slightly acidic in nature. Nitrogen, phosphorous, potash, and heavy metals (Zn, Cu, Cd, Pb and Cr) content in brewery sludge were higher than in the soil. The Zn concentration was highest whereas the Cd concentration was lowest in both soil and brewery sludge. Importantly, both in soil and BS, all of these heavy metals were lower than the permissible limits of United States Environment Protection Agency (USEPA) (USEPA, 1997).

Yield of Cauliflower

The effects of brewery sludge (BS) on curd yield of cauliflower were presented in Table 2. With the increasing application of BS, progressive increase in curd yield was observed. The highest curd yield (12.43 Mg ha^{-1}) was obtained from 20 Mg ha^{-1} BS rate whereas the lowest curd yield (7.01 Mg ha^{-1}) was recorded in control (Table 2). The curd yield obtained from 20 Mg ha^{-1} BS application was significantly higher compared to control and 5 Mg ha^{-1} BS application.

TABLE 1 SELECTED PROPERTIES OF BREWERY SLUDGE AND EXPERIMENTAL SOIL

Parameters	Brewery sludge	MPL of heavy metals in sludge*	Experimental Soil	MPL of heavy metals in soil*
pH	6.2	_	6.01	_
Organic matter (g/kg)	265.3	_	14.1	_
N (g/kg)	25.3	_	0.9	_
**P (g/kg)	6. 7	_	1.15	_
***K (g/kg)	7. 3	_	0.34	_
Zn (μg g^{-1})	558.47	3000	38.09	300
Cu (μg g^{-1})	75.23	1500	10.66	100
Pb (μg g^{-1})	33.88	1000	11.91	350
Cr (μg g^{-1})	34.98	1200	9.18	250
Cd (μg g^{-1})	2.25	20	0.73	0.6

*USEPA, 1997, ** Total phosphorous for BS and available phosphorous for soil
*** Total Potassium for BS and available potassium for soil, MPL = Maximum Permissible Limits

Heavy Metals Content in Soils

Soil Zn from 20 Mg ha^{-1}BS application was significantly greater (44.32 µg g^{-1}) as compared to 5 and10 Mg ha^{-1} sludge, and chemical fertilizer application, but similar to 15 Mg ha^{-1} application (Table 3). The application of 20 Mg ha^{-1} BS increased Cu concentration in soil significantly compared to other treatments. The lowest (10.92 µg g^{-1}) Cu concentration was found in control.

Accumulation of lead (Pb) in soil was highest (13.02 µg g^{-1}) in 20 Mg ha^{-1} BS application. The value was significantly higher compared to other treatments except in 15 Mg ha^{-1} BS application. The lowest (11.06 µg g^{-1}) Pb concentration was recorded in control (Table 3). The application of 5 and 10 Mg ha^{-1} BS, and chemical fertilizer had similar effects.

TABLE 2 EFFECTS OF BREWERY SLUDGE ON BIOLOGICAL AND CURD YIELDS OF CAULIFLOWER AT DIVYAPURI, NAWALPARASI, NEPAL

Treatments	Curd yield (Mg ha^{-1})
BS$_{0}$	7.01±0.42^{c}
BS$_{5}$	9.46±1.09^{bc}
BS$_{10}$	9.81±0.71^{ab}
BS$_{15}$	10.44±1.23^{ab}
BS$_{20}$	12.43±0.94^{a}
CF	11.00±0.95^{ab}
LSD$_{0.05}$	2.46
CV%	16.31

[a]Means followed by different letter(s) in column are significantly different at 0.05 probability level by DMRT

The concentration of Cr in soil obtained from the application of 20 Mg ha^{-1} BS was significantly higher than control and chemical fertilizer application. The highest concentration (9.98 µg g^{-1}) of Cr was obtained in 20 Mg ha^{-1} brewery sludge additions whereas the lowest (8.21 µg g^{-1}) concentration was recorded in the treatment with no sludge (Table 3). The cadmium concentration in soil increased with increasing the level of BS application from 0 to 20 Mg ha^{-1}, with highest (0.94 µg g^{-1}) value in 20 Mg ha^{-1} BS application. This treatment had significantly higher concentration of cadmium than BS$_{0}$, BS$_{5}$, and chemical fertilizer application, but similar concentration to BS$_{10}$ and BS$_{15}$ applications (Table 3).

Heavy Metals Concentration in Leaf and Curd of Cauliflower

Addition of BS increased Zn concentration of leaves from 38.76 (µg g^{-1}) in control to 60.91 (µg g^{-1}) in 20 g ha^{-1} BS (Table 4). There were no significant differences in Zn concentration among 5 to 20 Mg ha^{-1} BS additions but Zn concentration in leaves was significantly higher with BS addition as compared to chemical fertilizer. Similar pattern of increasing Zn concentration was also observed in curd but the concentration was lower compared to leaves (Table 5). Treatments receiving 15 and 20 Mg ha^{-1} BS rates resulted into the highest concentrations (5.36 µg g^{-1}) in leaf, which were significantly higher than control and 5 Mg ha^{-1} BS rates. Non-significant differences in curd Zn concentration were found among 10 to 20 Mg ha^{-1} sludge rates. However, the concentration of zinc in curd was highest in 20 Mg ha^{-1}BS application. The highest Cu concentration (5.35µg g^{-1}) in curd was obtained in 20 Mg ha^{-1} BS rate which was significantly higher compared to control and chemical fertilizer, but it was similar to other BS rates (Table 5).

The curd Pb concentration was highest (0.59 µg g^{-1}) in 20 Mg ha^{-1} BS rate which was significantly higher than control, 5 and 10 Mg ha^{-1} BS, and chemical fertilizer treatments (Table 5). The values obtained in 10 and 15 Mg ha^{-1} BS application were significantly higher than control and 5 Mg ha^{-1} BS. Chromium concentration in leaf increased with increasing sludge application ranging from 2.15 to 2.55 µg g^{-1}, and resulting the highest concentration in 20 Mg ha^{-1} BS (Table 4). Similarly, highest chromium concentration in cauliflower curd was obtained in 20 Mg ha^{-1} BS application. The Cr concentration in this treatment was

TABLE 3 EFFECTS OF BREWERY SLUDGE ON HEAVY METALS (ZN, CU, PB, CR AND CD) CONTENTS OF SOIL AT DIVYAPURI, NAWALPARASI, NEPAL

Treatments	Zinc (Zn) (µg g^{-1})	Copper (Cu) (µg g^{-1})	Lead (Pb) (µg g^{-1})	Chromium (Cr) (µg g^{-1})	Cadmium (Cd) (µg g^{-1})
BS$_{0}$	37.82±1.73^{c}	10.92±0.86^{b}	11.06±0.43^{c}	8.21±0.32^{b}	0.73±0.03^{d}
BS$_{5}$	38.95±1.39^{bc}	11.48±0.94^{b}	11.28±0.55^{c}	9.08±0.33^{ab}	0.83±0.02^{bc}
BS$_{10}$	40.25±0.98^{bc}	11.89±0.83^{b}	11.95±0.21^{bc}	9.55±0.45^{a}	0.86±0.03^{ab}
BS$_{15}$	42.32±1.10^{ab}	12.33±0.27^{b}	12.53±0.43^{ab}	9.60±0.65^{a}	0.90±0.02^{ab}
BS$_{20}$	44.32±1.65^{a}	15.85±1.23^{a}	13.02±0.40^{a}	9.98±0.61^{a}	0.94±0.03^{a}
CF	36.56±0.30^{c}	11.23±0.46^{b}	11.94±0.37^{bc}	8.56±0.01^{b}	0.75±0.02^{cd}
MPL*	200	50	300	400	3
LSD$_{0.05}$	3.47	2.34	1.00	0.84	0.08
CV%	5.75	12.66	5.58	6.11	6.47

*USEPA, 1997, MPL=Maximum Permissible Limits

[a]Means followed by different letter(s) in column are significantly different at 0.05 probability level by DMRT

TABLE 4 EFFECTS OF BREWERY SLUDGE APPLICATION ON HEAVY METALS (ZN, CU, PB, CR AND CD) UPTAKE BY CAULIFLOWER LEAF AT DIVYAPURI, NAWALPARASI, NEPAL

Treatments	Zinc (Zn) (μg g^{-1})	Copper (Cu) (μg g^{-1})	Lead (Pb) (μg g^{-1})	Chromium (Cr) (μg g^{-1})	Cadmium (Cd) (μg g^{-1})
BS_0	38.76±5.96^{bc}	6.37±0.76^{c}	3.23±0.29^{c}	2.15±0.08^{c}	1.30±0.26^{bc}
BS_5	50.76±0.94^{ab}	7.13±0.71^{bc}	3.76±0.18^{bc}	2.25±0.23^{bc}	1.21±0.22^{c}
BS_{10}	54.09±2.96^{a}	8.80±0.77^{ab}	4.42±0.21^{ab}	2.33±0.13^{abc}	1.32±0.25^{bc}
BS_{15}	56.67±2.39^{a}	8.95±0.09^{ab}	5.36±0.56^{a}	2.45±0.20^{ab}	1.39±0.27^{ab}
BS_{20}	60.91±4.30^{a}	9.85±0.47^{a}	5.36±0.35^{a}	2.55±0.17^{a}	1.51±0.27^{a}
CF	35.50±6.88^{c}	6.47±0.88^{c}	4.60±0.40^{ab}	2.14±0.07^{c}	1.27±0.24^{bc}
MPL*	99.4	73.4	0.3	2.3	0.2
$LSD_{0.05}$	14.07	2.07	0.98	0.24	0.13
CV	18.83	17.33	14.69	7.16	6.53

[a]Means followed by different letter(s) in column are significantly different at 0.05 probability level by DMRT
* MPL=Maximum Permissible Limits, FAO/WHO, 2001

TABLE 5 EFFECTS OF BREWERY SLUDGE APPLICATION ON HEAVY METALS (ZN, CU, PB, CR AND CD) UPTAKE BY CAULIFLOWER CURD AT DIVYAPURI, NAWALPARASI, NEPAL

Treatments	Zinc (Zn) (μg g^{-1})	Copper (Cu) (μg g^{-1})	Lead (Pb) (μg g^{-1})	Chromium (Cr) (μg g^{-1})	Cadmium (Cd) (μg g^{-1})
BS_0	33.81±0.34^{c}	4.32±0.21^{b}	0.27±0.03^{c}	1.05±0.04^{b}	0.32±0.01^{c}
BS_5	35.89±1.66^{bc}	4.65±0.22^{ab}	0.30±0.07^{c}	1.09±0.09^{b}	0.37±0.25^{bc}
BS_{10}	37.42±2.52^{abc}	4.89±0.41^{ab}	0.46±0.10^{b}	1.13±0.07^{b}	0.44±0.05^{ab}
BS_{15}	41.17±3.37^{ab}	4.95±0.25^{ab}	0.52±0.16^{ab}	1.25±0.12^{ab}	0.44±0.06^{ab}
BS_{20}	43.41±4.35^{a}	5.35±0.16^{a}	0.59±0.14^{a}	1.45±0.25^{a}	0.48±0.05^{a}
CF	33.74±0.54^{c}	4.10±0.18^{b}	0.44±0.02^{b}	1.02±0.03^{b}	0.33±0.01^{c}
MPL*	99.4	73.4	0.3	2.3	0.2
$LSD_{0.05}$	5.83	0.90	0.12	0.25	0.08
CV%	10.80	10.72	19.55	14.31	13.86

*FAO/WHO, 2001, MPL=Maximum Permissible Limits
[a]Means followed by different letter(s) in column 9are significantly different at 0.05 probability level by DMRT

significantly higher than all other treatments except in 15 Mg ha^{-1} BS application. Cadmium (Cd) concentrations in leaf (1.51 μg g^{-1}) and curd (0.48 μg g^{-1}) were highest in 20 Mg ha^{-1} (Table 4 and 5). The concentrations of Cd in leaf and curd obtained from 15 and 20 Mg ha^{-1} sludge were similar.

Discussion

Increased rate of brewery sludge application was associated with increased curd yield of cauliflower.

Thus, increased vegetable yield from sludge applied soils underlines the function of and contribution from higher macronutrients and organic matter content in the sludge (Jamil, Qacim, and Umar, 2006). A study showed that the fresh weight of lettuce (Mohammad and Athamneh, 2004) and fruit yield of cucumber (Hussein, 2009) was increased over control with increasing rates of sewage sludge application. Moreover, Akdeniz *et al.* (2006) reported that the highest yield of sorghum was obtained from the highest dose of sewage sludge application, and yield of sorghum showed no significant difference between the sewage sludge and chemical fertilizer.

The total heavy metal concentration in soil augmented with increased level of BS application rate compared to control and chemical fertilizer. Among the heavy metals accumulation in soil, Zn concentration was highest following Cu, Pb, Cr and Cd with increased sludge rate. Kumar and Chopra (2012) reported that the concentration of heavy metals (Zn, Cu, Pb, Cr, and Cd) in soil have positive linear relationship with the paper mill sludge application. Our results were in agreement with the findings of other researchers (Wong *et al.*, 2001; Mohammad and Athamneh, 2004; Hussein, 2009) who observed that the concentration of Zn, Cu, Cd, and Pb in vegetable grown soil progressively increased with increasing rate of sewage sludge application. Topcuodlu (2005) stated that repeated application of sewage sludge and solid waste results in gradual accumulation of heavy metals in soil and subsequently different environmental problems. The heavy metals concentration in our experimental soil was below the USEPA maximum permissible limits (USEPA, 1997).

Increased rate of sludge application results in greater accumulation of heavy metals in curd and leaf tissues. Similar results were reported in earlier studies by Mohammad and Athamneh (2004), and Hussein

(2009). Singh and Agrawal (2010) reported that Cd, Cu, Pb, Cr, and Zn contents in the edible part of mungbean increased significantly with sludge application as compared to the control. Kumar and Chopra (2012) found that there was greater accumulation of Zn, Cu, Cd, Pb, and Cr in French bean plants with increased rate of paper mill sludge application, and the concentration of these elements were more in leaves than in fruits. In leaf and curd, Zn and Cu concentrations were below the maximum permissible limits whereas Cd concentration exceeded the maximum permissible limits of FAO/WHO (2001). Cr concentration in curd was below the maximum permissible limits but it exceeded the maximum permissible limits in leaf at 10, 15 and 20 Mg ha^{-1} BS application. Pb concentration in leaf exceeded the permissible limits of FAO/WHO (2001) whereas the concentration in curd was below the limit in control and 5 Mg ha^{-1} BS application. Principally, human beings are exposed to soil contaminants including heavy metals via food chain (soil–plant–human) (Arora *et al.,* 2008). Hence, our study underlines the risks involved in the consumption of vegetables obtained from the soils receiving brewery sludge due largely to likelihood of human exposure to heavy metals.

Conclusion

The yield of cauliflower increased with brewery sludge application, but soil and plant tissues also incurred greater accumulation of heavy metals such as Zn, Cu, Cd, Cr and Pb with increasing rate of brewery sludge. Concentration of Cd, and Pb (except in5 Mg ha^{-1}) in curd of cauliflower exceeded the permissible limits of FAO/WHO (2001), although the heavy metals content in soil and sludge were within the permissible limits. Higher concentration of Cd and Pb suggest potential risks to human health through the consumption of cauliflower. Since the brewery sludge characteristics are within the permissible ranges, this sludge can be used for agriculture application. Future study should consider the application of brewery sludge on other crops and soil types, and human health risk assessment.

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Using of Rice Straw (*Oryza Sativa* L.) for Better Purposes Fabricating and Evaluating of Physical and Mechanical Properties of Fiberboard

Properties of fiberboard made from rice straw (*Oryza Sativa* L.)

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Abstract

This study investigated the physical and mechanical properties of the rice straw (Oryza Sativa L.) fiberboard. The fiberboards were made in two conditions i.e. untreated and hot water treated rice straw fiberboard. These were manufactured using urea formaldehyde adhesive. They were tested for certain physical and mechanical properties. The density of untreated and hot water treated rice straw which were respectively was 0.79 and 0.91 g/cm^3. The MOR of untreated rice straw fiberboard was 13.15 N/mm^2 ifit was 25.59 N/mm^2 for hot water treated fiberboard. The MOE of untreated rice straw fiberboard was observed 386.57 N/mm^2 but hot water treated fiberboard showed 1044.31 N/mm^2. It was found that treated fiberboard was better than untreated fiberboard in all tested properties except moisture content.

Keywords

Oryza Sativa; Physical Properties; Mechanical Properties; Modulus Of Rupture (MOE); Modulus Of Elasticity (MOE)

Introduction

Throughout history, the unique characteristics and comparative abundance of wood have made it a natural material for home and other structures, furniture, tools, vehicles, and decorative objects. Today, for the same reason, wood is prized for a multitude of uses (Regis 1987). Nowadays environmental and economical concerns are stimulating research in the development of new materials for construction, furniture, and packaging. Particularly many research studies have been conducted on composite panels from non-wood lignocelluloses materials in which most of them are nature-based renewable resources (Rowell and Roger 1998). These resources are abundantly available in many countries, including residues from annual growth crops and plants (Rowell 1996).

Annual plant materials are promising candidates for alternative lignocellulosic fiber composites. Several annual plant fibers such as flax, hemp, jute, kenaf, bagasse, corn, and bamboo have been the subject of extensive research for the manufacture of non-wood particle and fiberboards (Youngquist et al. 1993, Rowell 2001). The agro-straw materials are abundant, inexpensive, and readily available sources of lignocellulosic fibers. The basic challenge for board producers is to convert the agricultural straw materials into particle boards (PB), medium density fiberboards (MDF) or high density fiberboards (HDF) in a sound technical and economical process (Sauter 1996).

In the morphological structure, straw from wheat and rice is less homogeneous than softwoods or hardwoods. Straw contrary to wood contains a relatively large number of cell elements, that is, fibers, parenchyma cells, vessel elements, and epidermic cells that comprise a high amount of ash and silica. In a cross section, the epidermic cells are the outermost surface cells and are covered by a thin waxy layer. This layer lowers the wet ability of straw with water based formaldehyde resins. In addition, straw has a quite different chemical composition compared to wood. Straw has a higher content of hemicelluloses, ash, and silica, but a lower content of lignin compared with wood (Sudhakara and Sddhartha 1981).

Mclaughlan and Andersen (1992) tried many treatments to enhance the bond ability of fibers to bond with UF resins for the production of MDF. The treatments include exposure to wet and dry heat, compression with heat and heat in combination with chemicals. Almost all the treatments resulted in boards with reduced properties compared to the control. Zhengtian and Bingy (1992) mentioned that slight improvement of bond ability of straw can be achieved by destroying the waxy layers encircling the stem of straw, however, the bond ability was still very poor and the boards made still could not meet the requirements of common standards. Simon and Pazner (1994) investigated the influence of the hemicelluloses content of the self-bonding behavior of different raw materials including annual plants and concluded that there is a straightforward relation between the hemicelluloses content in the raw materials and the bonding strength of composites.

Some studies have been conducted on improving the performance of straw panels. It was reported that the fiberboards made from rice, wheat, and flax straws were upgraded by using a chemi-thermomechanical treatment (Markessini et al. 1997).

In this study, the properties of untreated rice straw fiberboard and hot water treated rice straw fiberboard were determined for evaluating as a raw material for fiberboard industry.

Materials And Methods

Rice straw was collected from a storage house of a villager from Baghmara, Batiaghata, Khulna (22° 48' 0'' N and 89° 33' 0'' E), and Bangladesh. After collection of rice straw, they were washed properly for removing impurities and kept for air drying. Air dried rice straw was cut into pieces approximately 2.5 cm long.

Half of the air dried rice straw chip was boiled at 120^0C for 12 hours for treated fiberboard.

Both the hot water treated and without treated rice straw chips were submerged into 20% sodium hydroxide (NaOH) solution separately for 24 hours.

Chips of both types were washed properly to remove NaOH. One 25 cm single disc laboratory atmospheric refiner was used for defiberation of both types of chips. Then the refined fibers were dried in the air. Next these were dried in an oven at 1030C to reduce moisture content at 4% and dried fibers of both types were kept in different sealed plastic bags until used.

In this study, 20% urea formaldehyde on the dry weight basis was used as a binding agent for the board. Fiber was mixed with adhesive uniformly by a blender. Then mat was formed on a steel sheet using an iron frame. The mat was pressed in a hot press for 60 min. at 0.8 N/mm^2 pressure but the coil of hot press was switched on for the first 30 min. The temperature was 1250C for making the board. The board was cooled and stored at room temperature until trimmed to their final dimensions of 30 cm × 30 cm.

The laboratory tests of physical properties and mechanical properties for both types of board were carried out respectively in the Wood Technology Laboratory of Forestry and Wood Technology Discipline of Khulna University, Bangladesh and in the Laboratory of Mechanical Engineering Department of Khulna University of Engineering and Technology, Khulna, Bangladesh. The tests of physical properties were carried out according to ASTM D 1037-100 (ASTM 2006) standard procedures. Mechanical properties were performed according to DIN 52362 (DIN 1984).

All the data, produced during the laboratory tests for characterization of physical and mechanical properties of each type of fiberboards, were analyzed by using Microsoft Office

Excel (2007) and SPSS (Statistical Package of Social Survey) software.

Results And Discussions

Physical Properties

It was found that the density of untreated fiberboard and treated fiberboard was 0.79 and 0.91 g/cm^3, respectively (Fig. 1). From un-paired T-test, it was found that there was a significant difference ($t=-4.722$, $df=6$ and $P<0.05$) of density between the two boards.

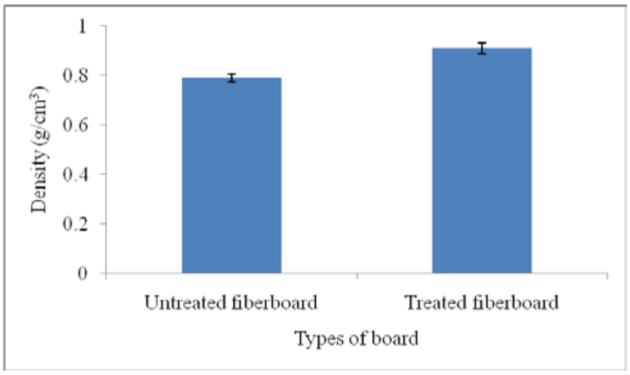

FIG. 1 DENSITY OF UNTREATED AND TREATED FIBERBOARD

The moisture content of untreated fiberboard and treated fiberboard was found to 12.29% and 9.4%, respectively (Fig. 2). There was no significant different (t=1.073, df=6 and P>0.05) between the two boards.

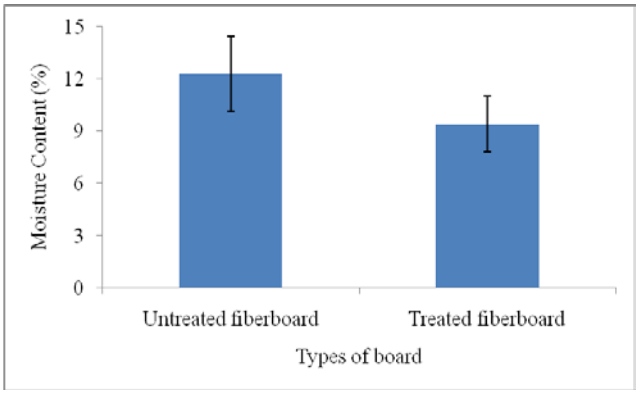

FIG. 2 MOISTURE CONTENT OF UNTREATED AND TREATED FIBERBOARD

It was found that the absorption of water by untreated fiberboard and treated fiberboard was 154.21 and 109.4%, respectively after 24 hours immersion in water (Fig. 3). It was found that there was a significant difference (t=4.083, df=6 and P<0.05) between the two types of fiberboard. This is lower comparing to bagasse MDF (76.40%) (Hosseinabadi et al. 2008).

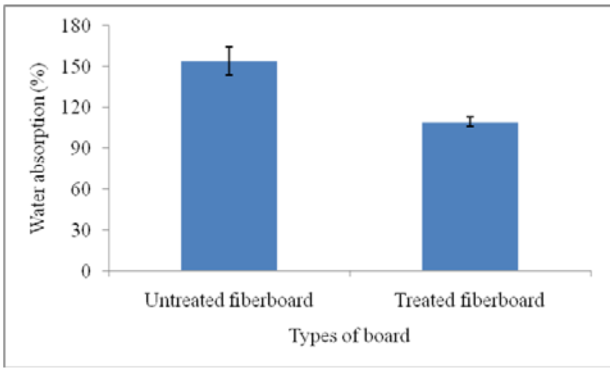

FIG. 3 WATER ABSORPTION OF UNTREATED AND TREATED FIBERBOARD

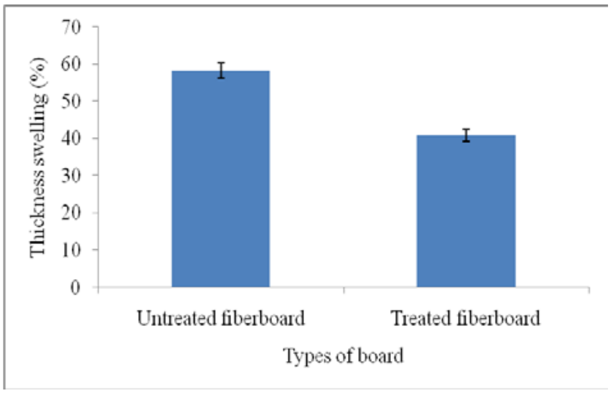

FIG. 4 THICKNESS SWELLING OF UNTREATED AND TREATED FIBERBOARD

After 24 hours immersion in water, it was found that the thickness swelling of untreated fiberboard and treated fiberboard was 58.28% and 40.76%, respectively (Fig. 4). There was also a significant difference (t=4.55, df=6 and P<0.05) between the thickness swelling of the two types of board. . It was 31.90 and 40.50% respectively for bagasse and wheat straw MDF (Hosseinabadi et al. 2008, Markessini et al. 1997). In this study, thickness swelling was higher than other findings but it was close too wheat straw for rice straw treated fiberboard (Hosseinabadi et al. 2008, Markessini et al. 1997).

Mechanical Properties

The MOR (Modulus of Rupture) of untreated fiberboard and treated fiberboard was found 13.15 and 25.59 N/mm², respectively (Fig. 5). The MOR of untreated fiberboard was significantly different (t=-4.091, df=4 and P<0.05) from that of treated fiberboard. The MOR was increased with the increasing of density. This was found in previous study (Xie et al. 2011). The MOR of straw and flax MDF were 6.00 and 11.30 N/mm² respectively (Markessini et al. 1997). The MOR of the both types was higher in comparison to the previous investigation.

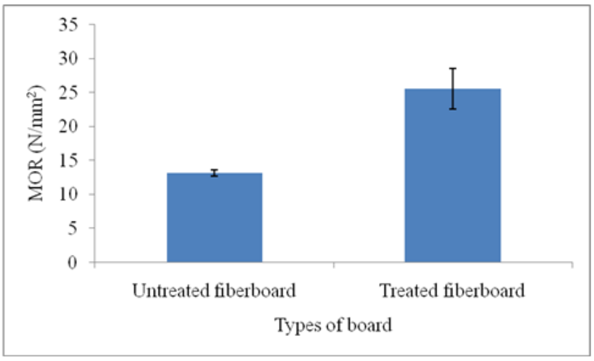

FIG. 5 MOR OF UNTREATED AND TREATED FIBERBOARD

The MOE of untreated fiberboard and treated fiberboard was found to 386.57 and 1044.31 N/mm², respectively (Fig. 6). It was also found that there was significant different (t=-11.559, df=4 and P<0.05). Density has an effect on the MOE and it increases with the increasing of density (Xie et al. 2011).

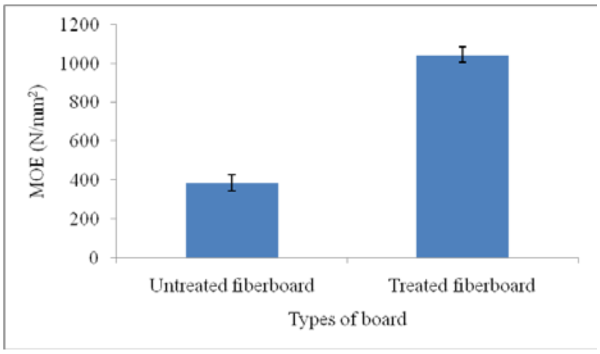

FIG. 6 MOE OF UNTREATED AND TREATED FIBERBOARD

Conclusions

All properties of treated fiberboard are significantly different and improved from those of untreated fiberboard except moisture content. Heat treatment improves partially certain properties. This heat treatment helped to achieve a substantial improvement of certain properties of untreated rice straw fiberboard. There is a possibility to use rice straw as a potential source for fiberboard manufacturing.

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