Concept Paper

An overview on the potential of agro-industrial wastes as fertilizer in aquaculture

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ABSRACT

Aquaculture is currently the fastest growing animal manufacturing field in the world and aquaculture in general and fish culture in specific can significantly contribute and help in alleviation of both qualitative and quantitative food shortages. A fertilizer is natural substance added to soil or land to increase its fertility. The type of fertilizer used and the rate of application can affect fish growth and yield by influencing the abundance and composition of natural food. Agro-industrial integration is an organic link between agriculture and industries that uses agricultural raw materials on one hand and manufactures agricultural inputs and agriculture that uses them on the other hand. Composting of sewage sludge provides an environmentally sound and energy saving solution to the increasing problem of waste management and disposal. It is also one of the most promising technologies for treating bio-solids allowing their recycling.

Keywords: Agro-industries; waste; fertilizer; aquaculture

INTRODUCTION

Aquaculture is currently the fastest growing animal manufacturing field in the world. The rapid expansion of aquaculture market is pronounced a lot in Asia which attributes concerning 90 per cent of the overall worldwide aquaculture production. The production of fish depends on the vegetation which is dependent on the nutrients in the ponds. It is not possible to increase the production of cultivated fish by giving them the greater quantities of natural food directly. The fertilization in fish farming is to improve water quality and to increase the variety and quantity of phytoplankton and zooplankton which eventually leads to high fish yield and economic returns. The ultimate goal of fertilization is to achieve suitable environmental conditions for the production of natural food for fish but in comparison with organic manure, fertilizers increase the level of primary productivity, algae abundance, dissolved oxygen, pH and total phosphates.

The population explosion is forecasting several challenges and the most important of them are food shortages and malnutrition. Aquaculture in general and fish culture in specific can significantly contribute and help in alleviation both qualitative and quantitative food shortages. Sugarcane by-products such as molasses and bagasse have been examined for their potential as fertilizers with favorable results. Pressmud is another sugarcane by-product. Its chemical composition compares well with that of cattle dung which is very popular as a manure among Indian aqua-farmers.

Aquaculture, like livestock and poultry production around the world is also subject to increasing environmental regulations. The two nutrients of greatest concern in fish farm effluent water are nitrogen and phosphorus. Soybean meal and distillers dried grains with solubles (DDGS) are relatively high in protein but much lower in phosphorus than fish meal. Substituting DDGS and soybean meal for fishmeal in aquaculture diets reduces the total phosphorus level in the diet and lowers the level of phosphorus in fish farm discharge water.

Fertilizers

Fertilizers are materials used to provide nutrients which are deficient in soils. A natural substance is added to soil or land to increase its fertility. Any natural or manufactured material which contains at least 5 per cent of one or more of the three primary nutrients (N, P_2O_5 and K_2O) can be called fertilizer (Anon 2000). Fertilizers have become a 'sine qua non' of agricultural production over much of the developing countries and will become so in most other areas before the end of this century (Anon 1991).

Fertilizers are applied to ponds to increase plant nutrient concentrations, stimulate phytoplankton growth and ultimately enhance production of fish or crustaceans (Boyd and Tucker 1998). The role of fertilizers in increasing the fish production has been emphasized in many studies under tropical and temperate conditions (Milstein et al 1995, Egna and Boyd 1997).

Fertilizers are applied to increase nitrogen and phosphorus concentrations for the purpose of promoting phytoplankton growth. Judicious organic fertilization of fish ponds can eliminate the need for supplementary feeding (Moav et al 1977).

In India mineral fertilizers probably accounted for only 2 per cent of food grain output in the early 1960's but by early 1980s the figure reached some 35 per cent (Anon 1987). Today it is no doubt even higher. In the early 1960s the developing countries (including China) accounted for 14 per cent of world fertilizer consumption.

Agro-based industry

As per the National Council of Applied Economic Research (1965) the agro-based industries are those which use agricultural raw materials for their industrial needs. They include seeds, fertilizers, implements, plant protective chemicals etc. These include only items but also repair and servicing of farm implements and machinery.

Agro-industrial integration is an organic link between agriculture and industries that uses agricultural raw materials on one hand and manufactures agricultural inputs and agriculture that uses them on the other hand.

Classification

The Central Food Technological Research Institute, Mysore, Karnataka gave a list of major processed product groups which they classified as ABI and food processing industries into nine groups viz (a) animal products, (b) beverage products, (c) cereal products, (d) confectionery and convenience food, (e) equipment and machinery, (f) fruit and vegetable products, (g) microbial and fermentation technology, (h) plantation and spice products and (i) protein and specialty foods.

Sugar industry

India is the world's largest producer of sugarcane and second largest producer of sugar after Cuba. But India becomes the largest producer if Gur and Khandsari are also included. This is the second largest agro-based industry of India after cotton textile industry. The major sugar producing states are Maharashtra, Gujarat, Uttar Pradesh, Haryana, Tamil Nadu, Punjab, Karnataka, Bihar and Andhra Pradesh.

Waste from sugar industry

Molasses: Molasses is the by-product separated from 'C' grade sugar during the centrifuging of sugar crystals. The yield of molasses per tonne of cane is in the range of 4 to 4.5 per cent. The entire quantum of molasses produced is being used for captive consumption in distilleries.

Bagasse: It is the fibrous residue from the sugarcane after extracting cane juice. Production of steam and power is done by using bagasse as fuel for the high pressure boilers in the cogeneration power plants.

Table 1. Composition of pressmud and cattle dung on dry weight basis

Parameter	Pressmud (g/kg)	Cattle dung (g/kg)
Total nitrogen	16.60	17.24
P_2O_5	10.81	12.22
Potassium	3.52	4.83
Ash	134.52	182.72

Pressmud: Pressmud, the solid waste produced while processing sugarcane is rich in potassium, sodium, phosphorous and organic matters used as a manure or as a landfill, is found to be useful as fertilizer. Pressmud being organic in nature could serve as a store house of macro and micronutrients. The large quantity of organic matter (771.7 g/kg) present in pressmud can act as a substrate for microorganisms. Table 1 gives the comparative composition of pressmud and cattle dung (Keshavanath et al 2006).

Distillery industries

Distillery is one of the most important agro-based industries and India is the fourth largest producer of ethanol in the world and the second largest in Asia. The distilleries produce ethyl alcohol from molasses. There were 319 distilleries in the country producing 3.25×10^9 liters alcohol and generating 40.4×10^9 liters waste annually (Santal and Singh 2013).

Waste from distillery industries

Spent wash: Distilleries generate large volume of foul smelling coloured waste water known as spent wash. Per liter of alcohol production on average generates 8-15 liters of effluent (spent wash) (Saha et al 2005). Distillery spent wash is not only high on organic and inorganic loading but also has dark brown colour even after bio-methanation.

Indian spent wash contains very high amounts of potassium, calcium, chloride, sulphate and biochemical oxygen demand (BOD) as compared to spent wash in other countries (Joshi 1999). Due to high concentration of organic load, distillery spent wash is a potential source of organic fertilizer.

As per Chidankumar et al (2009) spent wash can be conveniently used for the cultivation of top vegetables (creepers) without external (either organic or inorganic) fertilizers. Biswas et al (2009) reported that optimum level of spent wash or post-methanated effluent application could substitute chemical fertilizers and manure without sacrificing the yield of the crops.

According to Central Pollution Control Board, India the effluent is characterized by extremely high chemical oxygen demand (COD) (80,000–100,000 mg/l) and BOD (40,000–50,000 mg/l) apart from low pH, strong odour and dark brown colour (Bezuneh 2016).

Brewery industries

Beer is the fifth most consumed beverage in the world after tea, carbonates, milk and coffee and it continues to be a popular drink with an average consumption of 23 liters/person per year. The brewing industry has an ancient tradition and is still a dynamic sector open to new developments in technology and scientific progress (Fillaudeau et al 2006).

Waste from brewery industries (Table 2)

Sludge: Typically this consists of a range of heterotrophic microorganisms, organic particles from malt and hops, protein and tannin complexes, precipitated inorganic salts such as carbonates and oxalates with a BOD of 1,200 to 3,600 (Driessen and Vereijken 2003).

Spent grains: Brewer's spent grain (BSG) is the other major brewery by-product with difficulties and potential in disposal. Beer dregs are composed by dry weight of dry matter (26.3%), crude protein (23.4%) and crude fibre (17.6%) (Hough et al 1982).

Yeast surplus: Surplus yeast is recovered by natural sedimentation at the end of the second fermentation and maturation. This brewing waste has dry matter content close to 10 per cent. Stocks et al (2002) revealed that brewery compost from BSG enhanced the growth of plants such as tomato and geranium. Gutser et al (2005) also reported the availability of nitrogen content and biodegradability of various nitrogenous materials. The compost made up of BSG could be one of the cheap sources of compost and organic fertilizer.

Table 2. Composition summary of brewery wastes

Waste	Solids (% w/w)	C (% dry solids)	N (% dry solids)
Sludge	16	36	7
Spent brewer's grain (BSG)	24	53	2
Yeast	10	60	40

An antimicrobial effect against *Pythium* infestation of creeping bent grass was noted for brewery sludge compost (Craft and Nelson 1996). BSG has been more specifically targeted towards supporting fungal growth by its use in mushroom cultivation (Schildbach et al 1992).

Fruits and vegetables processing industries

This industry ranks fifth in the country and employs 16 lakh workers comprising 19 per cent of the country's industrial labour force. It accounts for 14 per cent of total industrial output with 5.5 per cent of the GDP. Its turnover is estimated at Rs 1,44,000 crore of which Rs 1,11,200 crore is in the unorganized sector. India produces 82 million MT of vegetables (10.9% of global production) and 47 million MT of fruits (8.4% of global production). However the level of processing of fruits and vegetables in India is about 2 per cent. This low level of processing results in 35 per cent wastage of total fruits and vegetables of the country that accounts for approximately Rs 35,000 crore per annum.

Waste from fruit and vegetable processing industries

Fruit wastes: Peel, rags and seed from citrus fruits; peel and stones of mango; rind and seed in jack fruit; cole and peel in guava; grape seed, stones and skin; pomace of apple

Vegetable wastes: Tomato seed, skin and trimming; asparagus wastes from canning; cods and husks from maize canning; vine and pods from pea canning; waste from canning and dry vegetables

Agro-based industrial waste composting

Composting is the natural process of decomposition and recycling of organic material into a humus-rich soil amendment is known as compost (Fig 1). Composting is the process of letting nature transform organic materials into a material with environmentally-beneficial applications.

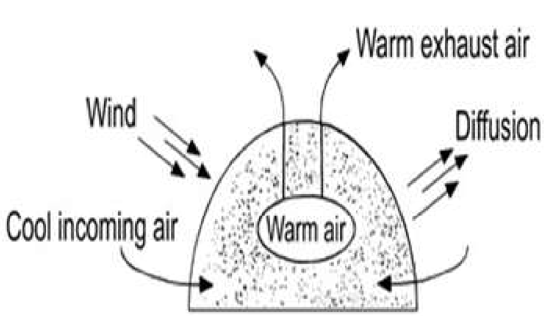

Fig 1. Basic raw material requirements for compost production

Table 3. Raw materials utilized for production of compost fertilizer from sugar pressmud

Raw material	Fraction	Percentage
Sugar pressmud	0.878	87.8
Local rocky phosphate	0.095	9.5
Molasses	0.005	0.5
SSP	0.02	2.0
Sulfur mud	0.002	0.2

The raw materials utilized for production of compost fertilizer from sugar pressmud are given in Table 3.

Composting methods

Passive composting or piling: It involves stacking the materials and letting them decompose naturally. This method is simple and low cost but is very slow and may result in objectionable odours.

Aerated static piles: Air is introduced into the stacked pile via perforated pipes and blowers. This method requires no labour to turn compost but is weather sensitive and can have unreliable pathogen reduction due to imperfect mixing.

Windrows: They are long, narrow piles that are turned when required based on temperature and oxygen requirements. This method produces a uniform product and can be remotely located. However turning the compost can be labour intensive or require expensive equipment. Windrows are typically used for large volumes which can require a lot of space. In addition windrows can have odour problems and have leachate concerns if exposed to rainfall.

Bins: The using wire mesh or wooden frames allow good air circulation. These are inexpensive and require little labor. Three chamber bins allow faster compost production utilizing varying stages of decomposition. Bin composting is typically used for small amounts of food waste.

In-vessel systems: These use perforated barrels, drums or specially manufactured containers that are simple to use, easy to turn, require minimal labour, are not weather sensitive and can be used in urban and public areas. The initial investment can be high and handling volumes are typically low.

Must to make and monitor agro-based waste compost

Proper nutrient mix or carbon to nitrogen ratio (C:N): It is important for bacteria to process organic material into compost. The optimum ratio to begin composting is 30:1.

Moisture content: Sixty per cent moisture content is optimal for microorganisms to breakdown the compost. Moisture content above 70 per cent creates anaerobic conditions, slow down the process and can create foul odours. Moisture below 50 per cent also slows down the decomposition process. The moisture content of fresh food waste is 80 to 90 per cent, sawdust is 25 per cent and yard waste is 70 per cent. Compost with a proper moisture content will form a clump and slightly wets the hand when squeezed.

Aeration or oxygen: It is essential for optimum microorganism populations to effectively breakdown the composting material. This can be done by turning, mixing and using the blowers, fans, aeration tubes, aeration holes or raising the compost off the ground.

Particle size: It can affect the rate of decomposition of compost. The smaller the particles the more aeration the compost receives and microorganisms can break down smaller pieces faster.

pH: pH levels from 6.0 to 7.8 are considered high quality compost. Proper C-N ratios should create optimum pH levels. Starting with a fairly neutral pH will ensure high levels of microorganisms for efficient decomposition.

Temperature: The compost is important while biological activity takes place in the decomposition process. Low outside temperatures slow down the process while warmer conditions speed up it.

Compost done to use in aquaculture as fertilizer

Mature or stable compost is similar to humus in appearance, smell and touch. The finished compost will no longer heat on its own thus maintaining the ambient temperature and there will be no weed seeds or pathogens. The pH will be near 7.0, the moisture content between 35 and 50 per cent, C-N ratio from 10:1 to 25:1 and the organic matter content between 40 and 65 per cent. It is important to protect the compost from wind-blown weed seeds until its point of use. Undesirable odours will not return even when the mature compost is rewetted.

It is very important not to apply unfinished or immature compost; it may have phytotoxins that can kill phytoplankton plants. An inexpensive way to test for mature compost is the watercress test. It is better to grow in immature composts because these are very sensitive to pH and nutrition.

Converting agro-based industrial waste to compost and use it in aquaculture as fertilizer (Fig 2)

Fertilizer is converted into fish flesh either by direct consumption of feed remains in the manure or

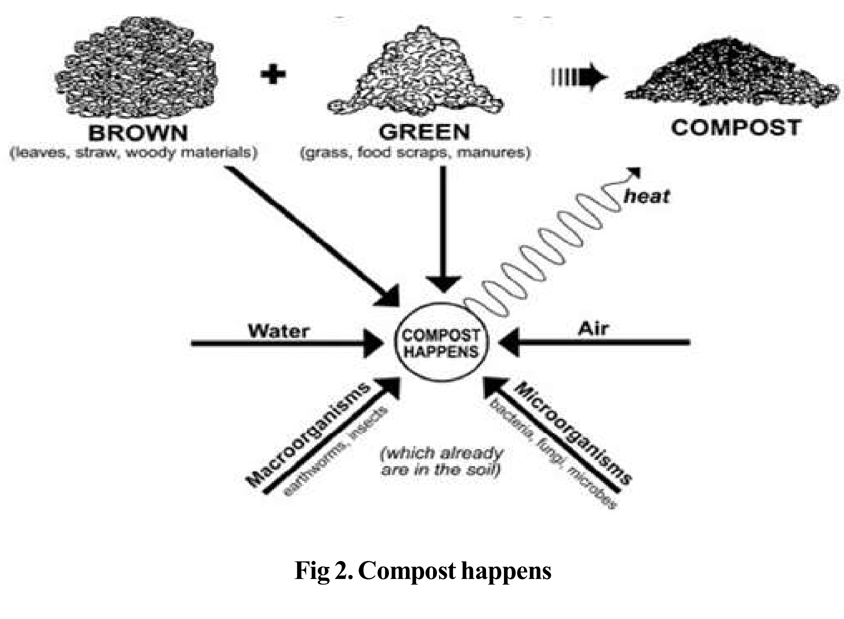

Fig 2. Compost happens

stimulation of pond ecosystem to increase autotrophic and heterotrophic production (Wohlfarth and Hulata 1987). The greatest dosage of pressmud leads to better growth of common carp as common carp is an omnivore (Jhingran 1982).

In terms of cost pressmud is 30 per cent cheaper than cattle dung. At equivalent doses of application (10,000 kg) production was 26 per cent higher with pressmud as compared to cattle dung (Middendorp1995). Keshavanath et al (2006) reported that pressmud could be considered as an economical and effective fertilizer than cattle dung in carp culture. Brewery waste and distillers-dried grain can be used as an alternative protein source to fishmeal.

Benefit of compost fertilizer

It contains 25-30 per cent organic matter; major nutrients like N, P, K, Ca, Mg and S; minor elements like Fe, Zn, Mn, Cu, and B to use as fertilizer in aquaculture; saves the cost on inorganic fertilizers by 15-20 per cent in aquaculture production; improves the structure, texture and quality of the soil in aquafield; the microbes produce enzymes, auxins and other growth regulators, amino acids and many other organic acids which help in the proliferation of the aquaculture system; rectifies the micronutrient deficiency of the soil and increases the fish yield of the product.

CONCLUSION

The direct use of agro-industrial waste fertilizers could be a low-cost technology to complete the bio-geochemical cycle of nutritional elements for aquaculture in organic or conventional farming and could also be a valuable opportunity to reduce the environmental and economic costs related to its disposal. Nowadays agro-industrial waste induces increasing problems due to the high economic cost and heavy environmental impact of disposal. Its potential reuse as organic fertilizer could represent a sustainable approach to recycling nutrients and reintegrating organic matter into soil.

The demand of fertilizer for aquaculture is increasing day by day due to intensification of systems as well as high production pressure. These wastes can be useful and a clean alternative for the mineral fertilizer. There is a need and huge opportunity of research and development to use these waste products as organic fertilizer for aquaculture.

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